









GUIDE TO THE STUDY OF ANIMAL ECOLOGY



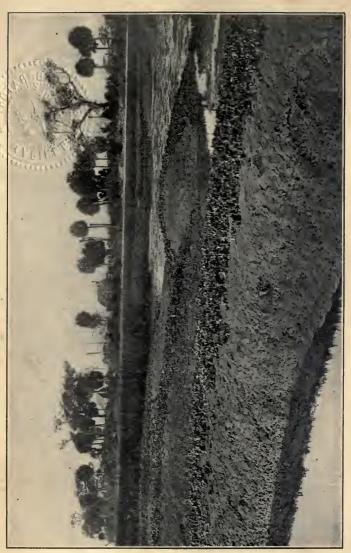


THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO · DALLAS
ATLANTA · SAN FRANCISCO

MACMILLAN & CO., LIMITED LONDON · BOMBAY · CALCUTTA MELBOURNE

THE MACMILLAN CO. OF CANADA, Ltd. TORONTO





Frg. 1.—Oyster Bank in South Carolina. Showing colonies of "coon" oysters growing in area between tides. Consult Möbius, Dean, and Grave for the ecological conditions of the animals on oyster hanks. representative animal community. Photo. by B. Dean, loaned by U. S. Bureau of Fisheries.

AR 17

GUIDE TO THE STUDY

OF

ANIMAL ECOLOGY

BY

CHARLES C. ADAMS, Ph.D.

ASSOCIATE IN ANIMAL ECOLOGY, DEPARTMENT OF ZOÖLOGY
UNIVERSITY OF ILLINOIS

New York
THE MACMILLAN COMPANY
1913

All rights reserved



COPYRIGHT, 1913, By THE MACMILLAN COMPANY.

Set up and electrotyped. Published August, 1913.

1002

Norwood Press J. S. Cushing Co. — Berwick & Smith Co. Norwood, Mass., U.S.A.

PREFACE

During the past ten years the writer has been trying to find some consistent and satisfactory working plan for handling the almost bewildering number of facts, of ecological significance, which have been accumulating in the literature of zoölogy, biology, and the allied sciences. This book is the outgrowth of the effort as it has developed in the study and teaching of animal ecology. I have not attempted to make this an exhaustive treatment of the subject, but rather to indicate briefly some of its general bearings and a method of approach. I have tried to keep in mind the needs of the beginner in ecology.

An ecological point of view is described more fully than the other subjects discussed, so that the student may see the need of familiarity with those tests or criteria by means of which he may be able to determine for himself ecological relations and the validity of ecological studies. The other phases are treated less fully in the discussions and with more detail bibliographically so that this may be a useful source book. The geographical (in the ordinary sense of the word) aspect has been deliberately omitted. The references should be looked upon from the standpoint presented in the general portions of this book, and if the facts and inferences aid in the interpretation of the relations which exist

between animals and the sum total of their environments, one may fairly consider that they are of ecological worth.

In the arrangement of the references I have tried to group related papers, but many defy any single system. Some of the publications deserve to be in several lists, but little duplication has been made, as this would unduly prolong the lists. The annotations will supplement the titles and their grouping in indicating the contents and importance of the papers for our purpose. It has often been difficult to select from several almost equally valuable and useful papers. Others with different interests, aims, and experience would doubtless make a different choice. It will therefore be a favor, if those who use this handbook and feel that important papers have been excluded, will communicate this fact to the author.

This book is not intended as a treatise on the science of ecology; its aim is primarily educational. This is the justification, if any were necessary, for placing emphasis upon the point of view and the importance of an understanding of explanatory processes and of the methods of scientific investigation. Any adequate treatment of this subject would exceed the space of this volume and it is reserved for future elaboration.

At present ecology is a science with its facts out of all proportion to their organization or integration. There is thus an immediate need of integration, and this above all requires a clear conception of the scientific method as a tool, and independent thinking as well. The fact that scientific work progresses more rapidly when consciously pursued than otherwise should serve as ample justification for this emphasis.

A word of explanation is desirable to explain certain features of this volume. It is the outcome of coöperative work on the part of the Illinois State Laboratory of Natural History and certain members of the Ecological Survey Committee of the Illinois Academy of Science, Professors E. N. Transeau and T. L. Hankinson. A local ecological study was made, as a piece of cooperative work, and directions for study were to be an introductory section of my part of this report. But as this part grew on my hands, with the permission of Professor S. A. Forbes, Director of the Illinois State Laboratory of Natural History, I decided to publish it separately. This part was written two years and a half ago, and when separate publication was decided upon, additional references to the literature were added to bring it to date. These circumstances explain the emphasis placed upon ecological surveying and also the brevity of treatment of other aspects.

Further, I am indebted to Professor Forbes for reading the manuscript and for valuable criticisms, and likewise, for similar assistance, to my wife, Alice Norton Adams. Skillful help on the proof and index has been given by Miss Marion E. Sparks.

CHARLES C. ADAMS.



CONTENTS

PREFA	CE	v
CHAPTE:		1
I.	AIM, CONTENT, AND I OINT OF VIEW	-
II.	THE VALUE AND METHOD OF ECOLOGICAL SURVEYS .	23
III.	Field Study	36
IV.	THE COLLECTION, PRESERVATION, AND DETERMINATION	
	of Specimens	49
v.	References to Scientific Technique	55
	1. The Scientific Method	55
	2. Directions for Collecting and Preserving Specimens,	
	Photographing, Surveying, and Other Phases	
	of Technique	57
	3. The Preparation of Papers for Publication and	
	on Proof Reading	65
VI.	REFERENCES TO IMPORTANT SOURCES OF INFORMATION	
	ON THE LIFE HISTORIES AND HABITS OF	
	INSECTS AND ALLIED INVERTEBRATES	70
3711	THE LAWS OF ENVIRONMENTAL CHANGE, OR THE "OR-	
A 11.	DERLY SEQUENCE OF EXTERNAL NATURE."	
	(THE DYNAMIC OR PROCESS RELATIONS OF	w.a
	THE ENVIRONMENT)	79
VIII.	THE LAWS OF ORDERLY SEQUENCE OF METABOLISM,	
	GROWTH, DEVELOPMENT, PHYSIOLOGICAL	
	CONDITIONS, AND BEHAVIOR, OR "THE LIV-	
	4	

CHAPTER	PAGE
ING ORGANISM AND THE CHANGES WHICH	
TAKE PLACE IN IT." (THE DYNAMIC OR	
PROCESS RELATIONS OF THE ANIMAL)	92
1. General Physiology and Development	95
2. A Selection of Physiological and Ecological Papers	100
3. Animal Behavior as a Process	102
4. A List of Selected Reviews and Bibliographies .	107
5. A Selection of References on Life Histories and	
Behavior	108
IX. THE CONTINUOUS PROCESS OF ADJUSTMENT BETWEEN	
THE ENVIRONMENT AND THE ANIMAL, WITH	
SPECIAL REFERENCE TO OTHER ORGANISMS.	
(THE DYNAMIC OR PROCESS RELATIONS OF	
ANIMAL ASSOCIATIONS AND AGGREGATIONS) .	122
1. The Struggle for Existence	123
2. The Dynamic Relations of Associations and Aggre-	
gations, with Special Reference to Animal	
Associations	130
a. The Relation of Animals to Pollination and to	
Plant Galls	141
b. Subterranean and Cave Associations	143
c. Selected References on Aggregations and Asso-	
ciations	145
INDEX	151
INDEX TO NAMES	170

LIST OF FIGURES

FIG.				
1.	An Oyster Habitat on the South Carolina Coast	t Fron	tisp	riece
2.	Struggle for Existence on a Clam Flat. Over-crowded Condition	facing	pag	e 7
3.	Struggle for Existence on a Clam Flat. Destruction of Clams by Predaceous Animals	66	66	8
4.	A Small Mountain Stream as an Animal Environment	66	"	86
5.	A Small River as an Animal Environment .	66	66	87
6.	An Illinois Prairie Remnant as an Animal Environment	66	66	139
7.	An Illinois Deciduous Forest as an Animal Environment	66	"	146

RELATION OF ECOLOGY TO BIOLOGY

"I shall try to show that life is response to the order of nature. . . . But if it be admitted, it follows that biology is the study of response, and that the study of that order of nature to which response is made is as well within its province as the study of the living organism which responds, for all the knowledge we can get of both these aspects of nature is needed as a preparation for the study of that relation between them which constitutes life."

"To study life we must consider three things:

first, the orderly sequence of external nature; second, the living organism and the changes which take place in it; and,

third, that continuous adjustment between the two sets of phenomena which constitutes life."

"The physical sciences deal with the external world, and in the laboratory we study the structure and activities of organisms by very similar methods; but if we stop there, neglecting the relation of the living being to its environment, our study is not biology or the science of life."

W. K. BROOKS.

ANIMAL ECOLOGY

I. AIM, CONTENT, AND POINT OF VIEW

ECOLOGY has no aim, but ecologists have. The problems of the ecologist are not fundamentally different from those of any other kind of naturalist. The superficial differences in aim are due to the different points of view, or methods of approach, rather than to any essential difference in the character of the problems.

The essentially biological core of ecology may be best shown by considering the relation which this science bears to other branches of biology, a relation which has been admirably expressed by the eminent physiologist, Burdon-Sanderson ('94, pp. 438–439), as follows:

"Now the first thing that strikes us in beginning to think about the activities of an organism is that they are naturally distinguishable into two kinds, according as we consider the action of the whole organism in its relation to the external world or to other organisms, or the action of the parts or organs in their relation to each other. The distinction to which we are thus led between the *internal* and external relation of plants and animals has of course always existed, but has only lately come into such

1

prominence that it divides biologists more or less completely into two camps — on the one hand those who make it their aim to investigate the actions of the organism and its parts by the accepted methods of physics and chemistry, carrying this investigation as far as the conditions under which each process manifests itself will permit; on the other, those who interest themselves rather in considering the place which each organism occupies, and the part which it plays in the economy of nature. It is apparent that the two lines of inquiry, although they equally relate to what the organism does, rather than to what it is, and therefore both have equal right to be included in the one great science of life, or biology, yet lead in directions which are scarcely even parallel. So marked, indeed, is the distinction, that Professor Haeckel some twenty years ago proposed to separate the study of organisms with reference to their place in nature under the designation of 'eccology,' defining it as comprising 'the relations of the animal to its organic as well as to its inorganic environment, particularly its friendly or hostile relations to those animals or plants with which it comes into direct contact.' Whether this term expresses it or not, the distinction is a fundamental one. Whether with the œcologist we regard the organism in relation to the world, or with the physiologist as a wonderful

¹ These he identifies with "those complicated mutual relations which Darwin designates as conditions of the struggle for existence." Along with chorology — the distribution of animals — ecology constitutes what he calls *Relations-physiologie*. Haeckel, "Entwickelungsgang u. Aufgaben der Zoologie," Jenaische Zeitschr., 1869, Vol. V, p. 353.

complex of vital energies, the two branches have this in common, that both studies fix their attention, not on stuffed animals, butterflies in cases, or even microscopical sections of the animal or plant body—all of which relate to the framework of life—but on life itself."

The quotations from Brooks, on a preceding page, show even more explicitly the intimate relation which exists between biology and ecology. At first glance they may seem to prove almost too much — that biology and ecology are synonymous. They show at least that ecology is concerned with fundamental biological problems — the responses of organisms to their complete environments.

The relations which different branches of ecology bear to one another may be discussed under three headings, individual, aggregate, and associational ecology. These phases are superficially so distinct that students of one branch may be almost unaware of the existence of the coördinate branches and may not realize that each is a part of the larger unit.

Individual Ecology. — The study of individual ecology is the investigation of the development (process of formation) of the structure, function, and behavior of a given individual or kind of animal from the standpoint of its relations and responses to the complete environment. All ecologically significant facts should be considered. Such a study may be devoted to an animal, as, for example, a bumblebee, a crawfish, or a garter snake, and may be limited to a single habitat or locality, or extended

throughout the entire geographic range of an animal. From this standpoint the individual studied becomes the hub of the microcosm, from which all relations and responses radiate. Most of the physiological studies of ecological bearing and many investigations of animal behavior have been made from this viewpoint. The organism is thus considered as an agent which, transforming and utilizing substance and energy, produces a varied number of physiological conditions and forms of activity, which in turn furnish the basis for the constant process of response between the organism and its environment.

Aggregate Ecology. — The study of aggregate ecology is the investigation of the ecological development, relations, and responses of animals based upon hereditary or taxonomic units, as in a family community, or in genera, families, orders, etc. These groups or aggregates are made the basis for the ecologic study, as a hive of bees, birds, dragon flies (Odonata), the genus Bombus. From this approach the activities and responses of the group are traced throughout all environments and associations within the area studied, or throughout the world, and its responses and adjustments to the whole environment receive primary attention. The hereditary or taxonomic unit is here the hub of the microcosm. Perhaps most of the contributions to ecology by the taxonomists are made from this standpoint. Here also the aggregate is considered as an agent or entity which produces many kinds of activities and adjustments to the environment.

Associational Ecology. — Associational ecology is devoted to the investigation of the development, interrelations, and responses of animals which are grouped or associated in the same habitats and environments. In this case the associates in a given association and habitat are considered as a unit, whose activities and interrelations and responses are investigated in the same manner as if it were a single animal. The interactions among members of an association are to be compared to the similar relations existing between the different cells, organs, or activities of a single individual. Such groupings have a composition which has developed into an arrangement, or "spacing," of individuals within it, and which produces a particular plan or pattern, as a result of the innumerable responsive activities on the part of the individuals which live together. For example, when the animals living in a small brook, the littoral zone of a lake, in a colony of breeding gulls, or on the floor of a forest, are treated as a unit, the entire history of the animals in the habitat is considered as a response to the conditions of life.

In this form of study the association becomes the center of all radiating relations and responses. Such an association is an agent which transforms substance and energy, producing varied physiological conditions and responses in the continuous process of adjustment "which constitutes life." The physiological needs and states of an association have as real existence in individual animals as have similar needs in the cell or cells which compose the animal body. The mere statement of the facts of such relations is enough to make valid such a comparison.

For the associational aspect of ecology the German naturalist, Möbius, proposed in 1877 the term "biocenosis." The meaning of this he expressed very clearly and concisely, and on account of its relatively obscure publication, in a paper devoted to oyster culture, it has not gained the circulation among zoölogists which its importance merits. His statement (Möbius, '83, p. 723) is as follows:

"Every oyster-bed is thus, to a certain degree, a community of living beings, a collection of species, and a massing of individuals, which find here everything necessary for their growth and continuance, such as suitable soil, sufficient food, the requisite percentage of salt, and a temperature favorable to their development. Each species which lives here is represented by the greatest number of individuals which can grow to maturity subject to the conditions which surround them, for among all species the number of individuals which arrive at maturity at each breeding period is much smaller than the number of germs produced at that time. The total number of mature individuals of all the species living together in any region is the sum of the survivors of all the germs which have been produced at all past breeding or brood periods; and this sum of matured germs represents a certain quantum of life which enters into a certain number of individuals, and which,



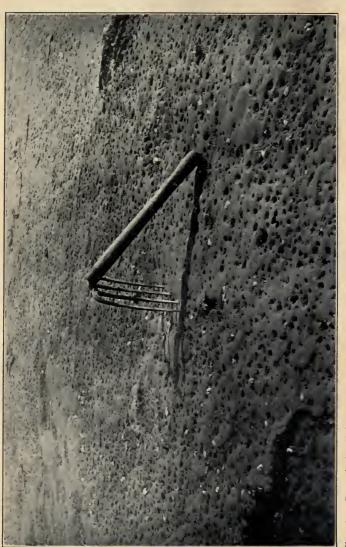


Fig. 2.—Struggle for Existence on a Clam Plat. Showing the overcrowded condition of a colony of Soft Clams (Mya arenaria) on Rowley Reef, Massachusetts. The pits mark the positions of the living clams. Photo. by Belding, loaned by Mass. Comms. Fisheries and Game.

as does all life, gains permanence by means of transmission. Science possesses, as yet, no word by which such a community of living beings may be designated; no word for a community where the sum of species and individuals, beings mutually limited and selected under the average external conditions of life, have, by means of transmission, continued in possession of a certain definite territory. I propose the word Biocanosis 1 for such a community. Any change in any of the relative factors of a bioconose produces changes in other factors of the same. If, at any time, one of the external conditions of life should deviate for a long time from its ordinary mean, the entire biocönose, or community, would be transformed. It would also be transformed, if the number of individuals of a particular species increased or diminished through the instrumentality of man, or if one species entirely disappeared from, or a new species entered into, the community." (See Figure 1).

The three methods of approach to ecological study are not so distinct as they appear at first thought. With perfecting knowledge the network of interrelations increases and the paths converge. Then also the study of the individual behavior of "social" animals, as ants, white ants, bees, or birds which live and breed in colonies, shows transitional stages from the individual unit to that of the family, the colony, and on to the association. Yet the advantage of each point of view should be recognized as an aid in the analysis and synthesis of any problem.

¹ From βlos, life, and κοινόειν, to have something in common.

Some students feel that the study of individual ecology should precede that of the associational. Within certain limits this is true, but if our general knowledge of biology had waited for the perfection of our knowledge of the individual cells of animals, the results would have been disastrous to all concerned. Even now our knowledge of these subjects is very incomplete. For similar reasons there should be no delay in studying animal aggregates and associations.

A combination of ecological and taxonomic study generally appeals most strongly to those students who have made a specialty of some group of animals. They are familiar with certain forms, have some confidence in taxonomic methods, and frequently have given some attention to habits, life histories, and to collecting. To those who like the descriptive aspect of taxonomy, ecological studies also offer a new field for further description and classification. At present perhaps the majority of ecological students have entered the subject through taxonomy. It is the almost universal verdict of such students that it has required much effort on their part to make the change in the point of view. Such a change cannot be made by a simple resolve, but requires a modification of the habits of the mind, which will be attended by a distinct consciousness of effort. As in other habits, reversion to the older attitude of mind is very easy. This change in point of view is a problem in habit formation, a study of the mental behavior of the ecologist, which is in reality the main topic



Fig. 3. - Struggle for Existence on a Clam Flat. Showing the destruction of Soft Clams by Horse-shoe Crabs (Limulus) and Cockles (Lunatia), Rowley Reef, Massachusetts. Photo. by Belding, loaned by Mass. Comms. Fisheries and Game.



thus far discussed. One may attempt to make such a change and find that he does not have sufficient modifiability to make it permanent, so that it is only for the moment, during actual collision with some stubborn fact, that he is able to realize ecological relations and an ecological point of view.

To the physiologist, however, individual ecology tends to appeal most strongly, and he, perhaps on account of the preponderance of analytical methods in his work, feels that this is the safest and most important aspect. This statement is perhaps also true of most students of animal behavior. This is largely due to the great present need of analytical methods in these lines, and perhaps indicates a stage in the development of their science rather than a permanent condition. Later a synthetic development will probably become more prominent, and with it will come a change in estimating relative values. Generally physiologists allow for a greater influence of the environment than do many other students. They are impressed with the dependence of organisms upon their environment, and the study of their reactions only reinforces this conception.

The ecologist who studies the responses of animals cannot help being impressed with the processes of adjustment, and with adaptation as a process. It is adaptation as a process, rather than as a product, which perhaps interests him most, and emphasis needs to be placed upon this distinction. The problem of adaptation as a process may be a different and separate one from that of evolution, but indi-

vidual animals must have shown adjustive adaptation, or there could have been no perpetuation to continue the struggle of adjustment. Ecological problems are likely to raise a question as to the relative importance of adaptation and evolution—if they are separate problems. The present generation has perhaps been more deeply impressed by evolution as a process, than by adaptation as a process.

The ecology of living animals is only the latest chapter in the volume on this subject; the preceding chapters will contain a history of the indefinitely long series of ecological responses which have taken place in the geologic past. Here is where the ecologist and paleontologist and geologist find common ground. The ecology of living animals must furnish us with whatever firm basis we have for the interpretation of the conditions of life in the past, upon which the paleontologist, stratigrapher, or paleogeographer must depend, at least in part, for his interpretations.

With still another training and interest, as in the case of those especially interested in human affairs, such as the sociologist, the physician, the sanitary expert, and the agriculturist, we may ultimately expect a greater appreciation for the associational aspect because of the social or associational character of human society. The associational is the phase of animal activity which may be considered as the form of animal behavior which has developed into the human social relations. It is a response to the complete organic and inorganic environment.

It is rather natural that in a relatively newly recognized subject like ecology this human aspect has not been very fully discussed. For practical reasons the ecology of man has been developed largely independent of that of animals; just as human physiology and psychology have been developed relatively independent of comparative or general physiological psychology. To the mutual advantage of these subjects they are now rapidly converging, and we may anticipate a similar relation between general animal ecology and the ecology of man. a general treatise on animal ecology the human phase should not receive undue emphasis any more than it should in a general physiology of animals or in a comparative psychology. But, nevertheless, the relationships of man and his animal associates (slaves, domestic animals, rats, mice, parasites, etc.) form as truly an animal association as do those of the animals which live associated in some forest glade; and in all probability, before any approximately complete understanding can be had of the human associations, their roots and principles of activity must be known and understood in the less aristocratic portion of his animal relatives.

The recognition of the associational aspect of ecology, as well as that human ecology is a part of general animal ecology, is of recent origin. This is very well shown in the following quotation from Huxley (1854. On the Educational Value of the Natural History Sciences):

"Biology deals only with living beings as isolated

things — treats only of the life of the individual: but there is a higher division of science still, which considers living beings as aggregates — which deals with the relation of living beings one to another — the science which observes men — whose experiments are made by nations one upon another, in battlefields — whose general propositions are embodied in history, morality, and religion — whose deductions lead to our happiness or our misery — and whose verifications so often come too late, and serve only

'To point a moral, or adorn a tale'-

I mean the science of Society or Sociology."

At a later date (1876. On the Study of Biology) Huxley says: "For whatever view we may entertain about the nature of man, one thing is perfectly certain, that he is a living creature. Hence, if our definition is to be interpreted strictly, we must include man and all his ways and works under the head of Biology; in which case, we should find that psychology, politics, and political economy would be absorbed into the province of Biology. In strict logic no one can object to this course. . . . The real fact is that we biologists are a self-sacrificing people . . . [so that] we feel that we have more than sufficient territory. . . . But I should like you to recollect that that is a sacrifice, and that you should not be surprised if it occasionally happens that you see a biologist apparently trespassing in the region of philosophy or politics; or meddling with human education; because, after all, that is a part of his kingdom which he has only voluntarily forsaken."

Whether sociology is regarded as a response of man to his fellows or to the whole of his environment is inconsequential in its bearing upon whether or not it is ecological. The response of man, as an animal, to a part or the whole of his environment is strictly ecological. Huxley recognized one relation very clearly, and that is that the ecological relations of individuals do not currently include the higher synthesis which deals with them as associations, or "aggregates" as he terms them. So far as known to the writer, human activities in general have never been fully and comprehensively oriented from the ecological standpoint, even by the humanitarians themselves, although some important preliminary steps have been taken. It looks as if such a viewpoint might give a new unity to all studies of human relations.

There is still another class of persons, particularly teachers and isolated students, who desire first of all to understand and interpret their own vicinity, and who will inquire which of the three plans their work best fits. If such a one begins with the detailed study of each species, the general survey will not be completed during his lifetime. If he uses the larger taxonomic units, he may survey the field by going over the same ground again and again, with each of the different groups successively in mind, until the entire field has been surveyed. Or, lastly, he may divide the area into associations and study the animals which are found living together, and by studying one association after another he may cover the entire field.

A teacher will find certain important advantages in this plan, and certain disadvantages. One of the most important considerations in its favor is that such a study results in a familiarity with the kinds of animals one actually finds in natural groups, as when his class is on an excursion. The natural history which a farmer, a fisherman, a summer vacationist, or a sportsman acquires is grouped in this same manner. Thus to a large number of people this is the natural method of approach, and is generally of most permanent value, except possibly to some professional teachers or zoölogists. One of its greatest disadvantages is that in most of the literature which one must use, the animals are not grouped in this way, but taxinomically.

The individual, aggregate, and associational methods of study are in themselves subject to diverse angles of approach, and each has its particular advantages and disadvantages. Of the methods of approach mention will be made of three only, the descriptive, the comparative, and the genetic or method of processes. The descriptive method must develop to some degree before the genetic problems can be adequately stated, and the mature development of the genetic may, and generally does, lag far behind that of the descriptive. The reason for this is simple, for it is evident that it is much easier to describe what we see than it is to explain how it originated or its process of development. At present biology as a science is mainly in the descriptive stage, though it is slowly but surely becoming explanatory and genetic. The developmental or explanatory method is so difficult that every possible expedient observation, comparison, reflection, experiment, etc. — must be used to secure the proper development of the main phases of ecology. There is a marked tendency in the naturalist to master one system of work, as observation or experiment, and to use it as a tool almost exclusively, turning from one phase of the subject to another, and continuing the use of the same method. This way of working is favorable to a good technique, but its weakness is that it often tends to give its user a feeling of the great superiority and reliability of the result reached by his method, and a correspondingly less appreciative recognition of results secured by other methods. To observe, to experiment, to reflect, to dissect, to stain, and to collect are only partial methods of investigation, and this fact should be realized and be kept in mind when estimating values and planning work.

The aim of the ecologist is professedly genetic or explanatory because it is the study of responses to all conditions of the complete environment. But these responses must be described, and the conditions influencing them as well, so that a descriptive aspect is an essential part in all phases of ecology. In the study of the responses of an individual, an order, or an association, pure description of the responses is necessary; but a description which will at once describe and show the working of the processes by which the results were produced, is of quite a different

order. This phase of explanation has been most concisely expressed and applied by the students of the physical sciences, and biologists may profit much from a study of their methods.

When, however, we turn to the viewpoint of the development of the science of ecology as a whole, a symmetrical development of the subject is most desirable. The preponderating influence of any special point of view tends, like dominance in general, to smother or suppress other germinating and competing ideas. The different special interests each have their advantages and disadvantages, as does a general interest. Diversity in students leads to diversity in the development of the subject, and a variety of emotional appeals to the student has its advantages. And just as the special student should devote some attention to the general bearing of his work, so also should the student of the general aspects cultivate some special field of interest.

The preceding discussion of the aims and methods in ecological study has been intended to indicate some of its general bearings, and to give the student some idea of the tests or criteria which may be used to aid in steering his course through the maze of observations which he may make and the opinions which he encounters. It is of equal importance for the student to be able to perceive ecological relations as recorded by others, because one person's experience is so limited compared with the general body of recorded fact and inference. Furthermore, there are also so many degrees and kinds of

work that go by the name ecological, which may or may not be, and so many also which are truly ecological but which do not pass under that name, that it is necessary that the student shall be able to see through its diverse guises and recognize its essential character. Whenever the question arises as to the ecological character of a fact, inference, or conclusion, its ecological validity may be tested in the following way:

Do the facts, inferences, or conclusions show a response to the inorganic or organic environment:

- 1. As an individual of a species or kind of animal?
- 2. As a group of taxonomically related animals?
- 3. As an association of interacting animals?

REFERENCES ON THE ECOLOGICAL STANDPOINT

In this I have listed only those papers which have seemed to me particularly significant because of their point of view, regardless of whether or not they are primarily zoölogical or specifically mention ecology.

Brooks, W. K.

- The Foundations of Zoölogy. pp. 339. New York. Introductory, pp. 1-29; Huxley, and the Problem of the Naturalist, pp. 33-46; Nature and Nurture, pp. 49-79.
- Heredity and Variation; Logical and Biological. 1906. Proc. Amer. Phil. Soc., Vol. XLV, pp. 70-76. An extremely suggestive paper which should be read by every ecological student.

GANONG, W. F.

1907. The Organization of the Ecological Investigation of the Physiological Life-Histories of Plants. Bot. Gaz., Vol. XLIII, pp. 341-344.

1904. The Cardinal Principles of Ecology. Science, N.S., Vol. XIX, pp. 493-498.

> Burdon-Sanderson, J. S.

1894. Biology in Relation to Other Natural Sciences. Smithsonian Report for 1893, pp. 435-463.

Möbius, K.

1877. Die Auster und die Austernwirthschaft. pp. 126. Berlin.

On page 72 he proposes the term "biocœnose" for the group of animals which live together in the same habitat. Not seen by writer.

1883. The Oyster and Oyster-Culture. Rep. U. S. Fish Comm., 1880, Part VIII, pp. 683-751.

Translation of preceding paper. On pp. 721-729 he discusses "An Oyster-Bank as a Biocönose, or a Social Community"; on page 723 he proposes the word "biocœnosis." An illuminating paper.

DAHL, F.

1902. Die Ziele der vergleichenden "Ethologie" (d. i. Biologie im älteren engeren Sinne). Verh. V. Inter. Zool.-Cong. 1901, pp. 296-300.

1908. Grundsätze und Grundbegriffe der biocönotischen Forschung. Zool. Anz., Bd. XXXIII, pp. 349-353.

1898. Experimentell-statistische Ethologie. Verh. der Deutsch. Zool. Gesell. Bd., 1898, pp. 121–131.

1901. Was ist ein Experiment, was Statistik in der Ethologie? Biol. Centralbl., Bd. XXI, pp. 675-681.

WASMANN, E.

1901. Biologie oder Ethologie? Biol. Centralbl., Bd. XXI, pp. 391-400.

WHEELER, W. M.

1902. 'Natural History,' 'Œcology' or 'Ethology'? Science,
N. S., Vol. XV, pp. 971-976.
Advocates the use of the term ethology.

St. HILAIRE, I. GEOFFRAY.

1859.

Histoire Générale des Règnes Organiques, Vol. II. Not seen by writer. Dr. W. M. Wheeler, of Harvard University, has kindly sent me the following note from p. 285. "'It is to ethology therefore that the fourth part of this work is devoted, to which belongs the study of the relations of organisms within the family and the society in the aggregate and in the community.' In a volume of the same work, page xx, St. Hilaire gives his program and speaks of the general facts belonging to ethological laws. These are defined as 'relating to the instincts, habits and more generally to the external vital manifestations of organisms." About the preceding Dr. Wheeler remarks: "You see this covers precisely the field which was a few years later called 'ecology' by Haeckel. Apparently the part of the work in which St. Hilaire wished to give a detailed account of the ethological phenomena of animals was not published. Only three volumes of the work exist. He died November 10, 1861, without having completed the work." Thus ethology has priority over ecology, but to my mind this fact carries no special weight, particularly since the word has become current in botany. To

LANKESTER, E. R.

1889. Article "Zoölogy." Ency. Britannica, 9th ed. Amer. Reprint. Vol. XXIV, pp. 842, 856.

Lankester defines "Bionomics. — The lore of the farmer, gardener, sportsman, fancier, and field naturalist, including thremmatology, or the science of breeding, and the allied teleology, or science of organic adaptations: exemplified by the patriarch Jacob, the poet Vergil, Sprengel, Kirby and Spence, Wallace, and

use a different name for the same subject or process in botany and zoology is as undesirable as to use a different term for heredity in plants and in animals.

nomics.' Buffon deliberately opposed himself to the mere exposition of the structural resemblances and differences of animals, and, disregarding classification, devoted his treatise on natural history to a consideration of the habits of animals and their adaptations to their surroundings, whilst a special volume was devoted by him to the subject of reproduction. . . . Buffon is the only prominent writer who can be accorded historic rank in this study." As I have access to but few of Buffon's writings, I quote the above. Bionomics is seen not to be synonymous with ecology, as defined by most students, although it includes much that is ecological. chaotic and unorganized "lore of the farmer" has no unifying or guiding principles, and although it contains many facts, from which a science may be built, to call it science seems undesirable.

Darwin. . . . Buffon (1707–1788) alone among the greater writers of the three past centuries emphasized that view of living things which we call 'bio-

It is of course advantageous in some ways to have agreement as to the limitations of ecology, or any science, but even the more exact sciences seem to fare little better, as is shown by the following statement: "It is not long since I heard a university professor begin a lecture on physics somewhat in this way: 'Physics is the science of matter and energy. This field is so large that it is customary at present to break off the physics of the molecule and its reactions and call it chemistry. Also to put to one side the physics of the heavenly bodies and call this a part of astronomy,' etc." (Strong, Science, N. S., Vol. XXXIV, p. 409, 1911.)

FORBES, S. A.

1895. On Contagious Disease in the Chinch-Bug (*Blissus leucopterus* Say). 19th Rep. State Ent. Ill. (8th Rep. of S. A. Forbes), pp. 16-176.

In this paper Forbes defines (pp. 16-18) ecology and points out, I believe for the first time, that economic entomology is simply applied ecology. He says, "The study of ecology is thus to the economic entomologist what the study of physiology is to the physician."

1909. Aspects of Progress in Economic Entomology. Journ. Econ. Ent., Vol. II, pp. 25-35.

Especially pp. 28-32 on the relation of ecology to economic entomology.

HERDMANN, W. A.

1896. Oceanography, Bionomics, and Aquiculture. Smithsonian Report for 1895, pp. 433-454.

EMERY, C.

1905. Éthologie, Phylogénie et Classification. C. R. 6me Cong. inter. de Zool. Berne, 1904, pp. 160-174.

CLEMENTS, F. E.

1905. The Foundations of Ecology, pp. 1-17.
Research Methods in Ecology. pp. 334. Lincoln,
Nebraska.

ADAMS, CHAS. C.

1906. Introductory Note. An Ecological Survey in Northern Michigan. Ann. Rep. Mich. Geol. Surv. for 1905, pp. 11-12.

1909. The Ecological Succession of Birds. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 121-154.

SHELFORD, V. E.

1912. Ecological Succession. V. Aspects of Physiological Classification. Biol. Bull., Vol. XXIII, pp. 331–370. The standpoint of this paper is very much in harmony with that advanced in this book.

CASE, E. C.

1905. Œcological Features of Evolution. Bull. Wis. Nat. Hist. Soc., Vol. III, pp. 169-180.

WHEELER, W. M.

1905. Ethology and the Mutation Theory. Science, N. S., Vol. XXI, pp. 535-540.

FLAHAULT, C., and SCHRÖTER, C.

1910. Phytogeographical Nomenclature. Reports and Propositions. III^o Cong. Inter. de Botanique. Bruxelles, 1910. pp. 28 + x. Zurich.

WHITE, C. A.

7 1893. The Relation of Biology to Geological Investigation. Ann. Rep. U. S. Nat. Mus. for 1892, pp. 245-368.

This paper and the two following references illustrate the intimate relation of ecology to phases of geology.

GRABAU, A. W.

1899. The Relation of Marine Bionomy to Stratigraphy. Bull. Buffalo Soc. Nat. Sci., Vol. VI, pp. 319-367.

WALTHER, J.

1893-94. Einleitung in die Geologie als historische Wissenschaft. I. Bionomie des Meeres. II. Die Lebensweise der Meeresthiere. III. Lithogenesis der Gegenwart. Jena.

Shows the close relation between ecology and geology.

The process standpoint is emphasized and the past is interpreted in terms of processes now in operation.

ADAMS, CHAS. C.

1908. Some of the Advantages of an Ecological Organization of a Natural History Museum. Proc. Amer. Associa. Museums, Vol. I, pp. 170-178.

II. THE VALUE AND METHOD OF ECOLOGICAL SURVEYS

"I cannot too strongly emphasize the fact . . . that a comprehensive survey of our entire natural history is absolutely essential to a good working knowledge of those parts of it which chiefly attract popular attention, — that is, its edible fishes, its injurious and beneficial insects, and its parasitic plants. Such a survey, however, should not stop with a study of the dead forms of nature, ending in mere lists and descriptions. To have an applicable value, it must treat the life of the region as an organic unit, must study it in action, and direct principal attention to the laws of its activity." — S. A. FORBES. 1883.

NATURAL history surveys have come down to us from the early days of zoölogy. These surveys have been of many kinds and have ranged from the adventurous accounts of early and daring explorers to those of such naturalists as Belt, Bates, Wallace, and Darwin, onward to the voluminous accounts of the "Biologia Centrali-Americana," and in the Challenger reports. These surveys have contributed greatly to our knowledge of the fundamental facts of zoölogy and to the training of naturalists.

The most frequent form of survey is that carried on along the lines which most nearly approach individual and aggregate ecology. Most of such surveys give only slight attention to the *responsive relation*, or only to its most general aspects. Surveys

of the usual character are of great importance, and with students of taxonomic training and interests only, this form of survey occurs very naturally. Most of the governmental and state surveys and museum expeditions are developed along these lines. The frequency with which such methods are used in surveys, which are expected to produce economic results, indicates that these methods are generally considered the most satisfactory. The exceptions to this rule are mainly surveys of fresh and salt waters, and are related in some way to aquatic resources. Except when detailed individual studies of certain species or some special subject has been made, the usual form of the reports of such surveys is the annotated list. It is rarely that even brief chapters discuss the groupings of the animals as they are found associated in nature. These statements show that, judging from the past, the methods currently used cannot be depended upon for a rapid and symmetrical development of ecology, or for the best development of ecological surveys. These must be developed in a more direct and deliberate manner, by carefully planned and executed ecological investigations. It is desirable also that ecological surveys should be conducted along some one of the three main avenues of approach, individual, aggregate, and associational, in order that the science may develop symmetrically. The following are some of the reasons which may be mentioned in favor of such surveys:

As a record of the associations, their interrelations

and responses to their environment — before they have become too much changed or exterminated. This is a duty to future naturalists and to future science. The animal remains in themselves are only a very incomplete record; their activities and environments are an essential part of the animals and should also be preserved.

The study of original conditions is a simpler problem than after interference by man, but excessive modifications result in the simplicity due to annihilation and a corresponding imperfection of knowledge. The value of a knowledge of original conditions tends to increase with time, and will aid much in future interpretations when there is still more disturbance. Thus an important perspective may be developed which will aid in estimating relative values. At the present time the loss of records of original conditions is only beginning to be felt. The possibility of making certain records will vanish with each generation. It is not even desirable to preserve all, but it is evident that many ecological records should be preserved.

As the importance of ecological studies, in natural environments, comes to be more generally recognized the serious encroachments of civilization upon habitats and associations is enforced upon us. Not only are the descriptions of these associations very few in number, but the interrelations of the animals in them are even less known, and the chances of preserving adequate records before their complete extinction are becoming fewer every year. Without the least disparagement of other lines of work, one can but wonder if the naturalists of the future will commend our foresight in studying with such great diligence certain aspects of biology which might be very well delayed, while ephemeral and vanishing records are allowed to be obliterated without the least concern. These changes are generally greatest where civilized man is most dominant, and in progressive attenuations, zones, or strips, the degree of change produced by him radiates. Ecology has developed only at a late stage in civilization, after much of the environment has undergone great changes, so that in order to study the original conditions, which are of such great historic and genetic significance, he must make long journeys, or invade the swamps or sterile uplands which man has not vet been able to reduce to the average conditions best suited to his needs. This state of affairs is one which, at times, makes him thankful that there are conditions which, for the present at least, man cannot cultivate and utterly change and mutilate. Some appear to think that an interest in such original conditions is of no particular scientific value, or is largely one of sentiment; still others, that such studies have no practical value. But if we come to consider that the original primeval conditions give us our best conception of the normal processes of nature and are comparable to the normal health of an organism, it puts the subject in another light. A pathological condition is, of course, a state in a natural process, as is also any disturbance

of the normal order of nature by man, and each should be studied scientifically. But the science of pathology has developed best as a study of the disturbances of normal processes and is interpreted primarily in terms of the normal; and the artificial should be similarly interpreted — the natural being the basis to which all standards must be referred. A comparison may also profitably be made between natural conditions and the physiological and vital optima of organisms and to the responses which are made with departures from such conditions. Similar comparisons should be made in the study of the responses of aggregations and associations in natural environments and departures from them. No matter how much we learn, the normal must remain as the ideal, and all departures from and disturbances of such conditions must be interpreted in terms of this fundamental unit.

To study disturbed, artificial, and "pathological" conditions, without an adequate knowledge of the normal and original conditions of both the organisms and the environment, is an attempt to interpret the abnormal and artificial in terms of itself, rather than in terms of the normal. If, however, the normal is no longer preserved, then its nearest approach should be studied, but with all the more care and caution. With a proper understanding of the normal, the disturbances made by man will be capable of interpretation in an orderly sequence strictly comparable to that found in the original and natural conditions. The cutting down and washing of the lands, the draining and filling of depressions, the flooding of the lands, the destruction (or succession) of plant and animal associations (including crop rotation), are processes brought about or practiced by other organisms or animal agencies. An ecological standpoint gives us a consistent, comprehensive orientation of all these natural and "artificial" activities and processes, and shows the unity in all organic responses to the environment. Man's influence in the main consists of hastening or retarding "natural processes."

Naturalists have for a long time spoken of the "balance of nature" and of the all-pervading influence of any serious disturbance of it. This balance is, of course, only a relative condition, and not absolutely fixed. It swings from one side, then back, sometimes showing considerable amplitude in its swing, then again its moves are very slight, mere tremblings, as it were. But now and then some local catastrophic event occurs which overturns everything, as when a volcano becomes active, or some dominant association takes possession of the field. - as in the case of man, - and a new order is initiated and a new balance is developed. The mongoose in Jamaica, our English sparrow, and rabbits in Australia are the classic examples of the overturning of the local order of nature by the agency of other organisms. Obviously this balance is not a condition limited to any particular locality or group of organisms. Balance is very generally conceded to be of fundamental importance in the study of any

species or group of organisms, if its place in the economy of nature is understood. A vast number of the problems of the economic zoölogist are thus problems, not so much of individual or aggregate ecology, but ones in which the balance of the whole local biotic association is concerned.

This was the fact pointed out by Möbius when he studied the oyster and came to see that it must be studied not in isolation but as a member of a community, association of animals, or a biocomosis, as he called these interrelated organisms. These facts are mentioned, as examples from a vast number that are recorded, to show that our applied or economic zoölogy and entomology are fundamentally more closely related to associational ecology than to any other phase of zoölogy, and to suggest that it would be to the great advantage of the students of such problems if they clearly understood this relation. This is also an argument for the ecological organization of a vast number of natural history surveys, because the associational grouping of observations and responses gives the most intimate knowledge of the life of animals in the network of their environmental relations.

In addition to the balance of nature which is found within the small associational units there are the larger ones of considerable geographic extent, which the students of faunal or floral problems frequently call zones or distinct regions. Some of these are distinct ecological units, whose *dynamic status* should be determined, so that we may know and

understand whether it is in a condition of stress, a process of adjustment, or one of relative equilibrium or balance. Under present conditions in what direction does it tend to move? At what rate? The non-ecological surveys have not put these questions or worked deliberately toward a goal which will answer them. For any comprehensive study of this character we need to have determined what may be considered as a biotic base, optimum, or balance, toward which relations under given conditions tend, and at which an equilibrium will become established (The Auk, 1908, Vol. XXV, p. 125). Such facts underlie all of the problems involved in the interpretation of climax biotic associations, and their application by man. Cook (1909, Bull. 145, Bur. Plant Industry, U. S. Dept. Agriculture, pp. 7, 8) has expressed similar relations as follows: "Unless we can form a definite idea of the original conditions we cannot expect to judge of their influence on primitive man, nor can we determine what effects man has had upon the vegetation and other natural conditions. We need what might be called a bionomic base line, an idea of the conditions which existed before man came upon the scene, the conditions which would again supervene if the human inhabitants were withdrawn."

It is perhaps significant that the genetic or successional relations of habitats and associations, as contrasted with their descriptive classification, both in plants and animals, have in the past been developed, not by the ecological students who live and work among

conditions greatly modified by man, as in parts of Europe, but in the newer, less modified America. In this respect a parallel exists to the development of our knowledge and the process and genetic interpretation of topography, which has also developed more rapidly in America than elsewhere. The process and genetic method which has developed in this physical science has now spread to the biological sciences and has found a fertile soil there for development on account of the *relatively* undisturbed biotic conditions which still persist in certain areas.

In this connection it may be worth while to indicate some of the ecological disadvantages under which the non-ecological surveys are carried on. As a rule, such surveys feel no strong obligation to record fully the conditions of the environment, or its developmental processes. The environment is considered as static, and not as a changing medium; it has no past or future, it has merely horizontal extension. The problem as to its dynamic status, whether in a condition of stress, in the process of adjustment, or in relative equilibrium, is not raised, or if it should be, it could not be handled. The student eager for new and little-known species is not the one to study such relations, at least, as a rule, this has not been his practice. So long as the success of a day's work is measured by the length of the list of novelties secured, rather than by the quality and quantity of ecological relations discovered, such students and surveys will not contribute greatly to our knowledge of the economy of nature in the regions surveyed.

At the present time it is very difficult to secure trained men to do ecological surveying. Even a superficial examination of this paper should show that familiarity with ecologic methods and results is not one to be acquired offhand, but a knowledge which requires considerable special training; not only as much as is usually required for other kinds of zoölogical work, but generally more, because of its synthetic relational tendency which requires a broad knowledge as well as some special knowledge in several lines of biology and the allied sciences. Conventionally considered, a properly equipped physiologist must have a working knowledge of certain phases of modern physics and chemistry in addition to his grounding in biology. A properly trained anatomist should have a knowledge of physiological and developmental processes, or his anatomy is purely descriptive and static. A student of general zoölogy should be grounded not only in physiological and developmental processes, but also in the relations of the organisms to their complete environment. The ecologist requires also the grounding in physiological, developmental, and ecological processes of adjustment, but as well he must understand the processes by which the vegetation and the physical environment have been and are being developed and their method of mutual interrelations and adjustment. It is difficult for some students to develop the ecological phases in the field. There are many disadvantages to be overcome. The difficulties are similar, in some respects, to those of the ethnologist

who is sent on some museum expedition. The wealthy donor of the funds may wish to see a room filled with specimens on the return of the ethnologist, so that materials which have bulk and make a showing take precedence over detailed studies of the habits, traditions, languages, and descriptions of the people, because such studies require appreciation rather than inspection for evaluation. The zoölogical student may meet with just the same kind of difficulty. His institutional authorities often judge values by the cubic foot and pound, rather than by the quality of relations discovered. The student himself who has had an extensive collecting experience, in which quantity and variety have been the ideal, finds it difficult to return from a day's work with only a few pages of notes on the responses of the animals, and with perhaps only a few specimens.

With such an understanding of the general rules of the game we may turn to the application or art of ecology, to indicate its relation to general problems. With a grounding in the general principles of organic response to the total environment, one is able to see that the disturbances due to man are a problem in the adjustment of the highest type of animal, as a member of an animal association, to its complete environment. The "control of nature" for which men strive is the process of making the environments and associations to order. The disturbances in the natural order may be looked upon as so many huge experiments or trial activities in this process of adjustment.

If natural preserves are not made, how will the next generation be best grounded in the general principles of the science? Are these complex modified conditions the natural place to start the student. or should such problems be reserved for the maturely trained one? These disturbed fragmentary conditions may be likened to fragmentary fossils whose interpretation is attempted. A paleontologist whose only knowledge of animals was derived from such fragments, and who had never known a perfect living animal, would certainly be at a great disadvantage in such an investigation. The natural starting point therefore seems to be in as nearly natural normal environments and associations as is possible, and with such experience one is prepared for the more complex problems resulting from man's activity.

By way of conclusion, some of the main advantages of ecological surveys are:

- 1. The record of natural environments and their associations for future generations.
- 2. The study of natural biotic conditions giving a perspective not derived in any other way.
- 3. The clearer conception of the *dynamic relations* of the balance of nature, biotic base, and climax associations.
- 4. Emphasis of the *process and interpretative* phase of scientific investigation over that of purely descriptive study.
- 5. Facilitating the invention of multiple working hypotheses which bear upon animal responses in nature.

- 6. Furnishing important conceptions to the study of the processes of adaptation and the struggle for existence.
- 7. Furnishing important general principles of great value in applied ecology.
- 8. Furnishing one of the best methods of learning how to get acquainted with the living aspect of the animals of any region.

III. FIELD STUDY

"Is not the biological laboratory which leaves out the ocean and the mountains and meadows a monstrous absurdity? Was not the greatest scientific generalization of your times reached independently by two men who were eminent in their familiarity with living things in their homes?" — Brooks, 1899, p. 41.

In taking up field work, or any other kind of complex study, a definite working plan is of much value. For this reason this subject deserves more than a mere mention. Such a plan greatly aids in keeping in mind the general aim of the study, and particularly the lesser aims which develop with the analysis of the subject. It further aids in the proper orientation and subordination of allied subjects which crowd in from all directions.

For many students it is a good plan to make out a general outline of any proposed study as soon as possible after the work has been started. In the beginning it is difficult to realize the radiating relations of a subject, and the attempt at such plans aids in the perception of these relationships and becomes an important guide. Such an outline will need several revisions, but these changes will come with a broadening and deepening grasp of the subject. Perhaps the greatest value of such a plan is that it facilitates the conscious effort to seek a defi-

nite goal by maintaining a standard of measurement.

In addition to a comprehensive analytical plan others are useful. Particularly is this true when several lines of work are being done simultaneously or when the work must be interrupted frequently. Under such circumstances even a daily program may aid in utilizing many of the fragments of time which are so easily lost. In this way incomplete observations, verifications, and similar small items which are time-consuming may be made. These plans apply with particular force to field study when several lines of observation are being driven abreast. I have found it profitable to keep memoranda on note slips which will recall items needing further attention, at certain places in the field or on certain subjects. Thus, for example, if plans are suddenly changed and another locality is visited, the proper note slips indicating the points for special study at such a place are quickly secured, and one can hasten to the field prepared for the work of the day. Of course, similar plans are applicable to many kinds of work.

To learn how to study in the field, and not simply to collect, is one of the most important habits which a field naturalist and the ecologist has to acquire. This is one which he must, to a large degree, master alone, without the ready access to assistance, as is usually the case in the laboratory study. It is also a subject about which it is difficult to give useful suggestions, other than those of the most general nature.

Directions for collecting are, on the other hand, simpler and more accessible in the form of numerous manuals filled with practical suggestions.

Field study is not confined to observations alone, but to the securing of all kinds of evidence from the field which will aid in the interpretation of the field relations of animals. Thorough intimacy with the animals can only be acquired through repeated and prolonged excursions in the field. This may mean excursions at any hour of the day or night. Part of this familiarity is best acquired by an intensive study of some limited area or association, and by thus establishing a unit for comparison so that the differences in other places are more readily perceived and described.

Before selecting a limited area for study one should make a general examination of a much larger tract, so that one may be sure that the area selected is a fair sample and worthy of the special study. There are also many advantages in selecting areas little modified by man. Such modified areas may, to better advantage, be considered later; just as pathology should be studied after one is grounded in normal histology. Undoubtedly the normal, or its approximation, is the best foundation upon which to build, and here we have the educational argument for natural preserves for animals and their superiority over highly modified "parks" for the same purpose.

Having selected a locality, repeated and prolonged visits, careful observation, and description of the place and animals will enable one to acquire the desired familiarity. For the study of the behavior of the animals concerned many observations can be made by remaining quiet, carefully concealed, and recording all observations. This method is particularly applicable to animals which live in exposed places, such as many insects, birds, and mammals. For other kinds, only indirect methods of observation are possible, or only when under controlled conditions. For the indirect methods of observation many forms of traps have been devised, traps not intended merely to receive the dead animal, but those also which will secure the animal and reveal something of its behavior. For the study of the habits and behavior of such animals as live in the soil or under bark, etc., both extensive collecting and examination of the animals in vivaria will also be necessary.

Fortunately for the student of mammals, birds, and fishes we have excellent guides for the technique of study and photographing of individual and associated kinds in the works of Kearton (1907), Chapman (1900), Herrick (1905), and Reighard (1908). It is very desirable that these methods be applied to the interrelations among the animals of an association. The student of behavior in nature has much to learn from many excellent studies of animal behavior which have been carried on in recent years by laboratory students. Fortunately the line between these two methods of study is breaking down to the mutual advantage of each. The border line between these two methods will give excellent re-

turns to any student well prepared in each line of work.

Another essential for good field work is a clear understanding of what ecological studies attempt to do. This implies some general conception of what is worth while ecologically; it assumes a point of view or other criterion which may be applied to test the trueness of one's aim. The ecologist will meet with much more than ecological facts, but it is to these that he should give primary attention. These accessory facts, no matter how interesting in themselves, should not divert him from the main course. The ecologist must select from this mass of experience those facts, inferences, and conclusions which help in the interpretation of the responses of animals to their complete environment. It is thus evident why the ecologist must have a clearly defined aim, with criteria for estimating values, or he will be at the risk of dissipating his energies. This phase of our problem as applied to the studies of a geologist, but applying with equal force to the ecologist, has been concisely expressed by Van Hise (1904, pp. 611-612) as follows: "I have heard a man say: 'I observe the facts as I find them, unprejudiced by any theory.' I regard this statement as not only condemning the work of the man, but the position is an impossible one. No man has ever stated more than a small part of the facts with reference to any area. The geologist must select the facts which he regards of sufficient note to record and describe. But such selection implies theories of

their importance and significance. In a given case the problem is therefore reduced to selecting the facts for record, with a broad and deep comprehension of the principles involved, a definite understanding of the rules of the game, an appreciation of what is probable and what is not probable; or else making mere random observations. All agree that the latter alternative is worse than useless, and therefore the only training which can make a geologist safe, even in his observations, is to equip him with such a knowledge of the principles concerned as will make his observations of value."

Early in field work one should learn that the collection of specimens is not the primary aim of excursions, that specimens are only *one* kind of facts, but that field study should be devoted to the accumulation of specimens, and to observations on the habits, activities, interrelations, and responses of animals, as well as to all facts, inferences, and suggestions which are likely to be of use in the interpretation of the problems studied.

We sometimes hear that reflections upon the work should be reserved for the return to the laboratory or study. This advice seems to be based upon the assumption that study in the field is not particularly stimulating and suggestive. On the other hand deliberating interpretatively in the midst of the problems under consideration is one of the most favorable conditions possible for the improvement of the quality and quantity of one's work. It should be recalled in this connection that Darwin and Wallace's evolu-

tionary theory did not originate in the laboratory, but while in the field in the midst of their studies, while working reflectively upon their observations and collections, as Brooks indicates in the quotation at the beginning of this chapter. The classic case of Bates discovering mimicry in his London study instead of in the forests of Brazil is to some minds not an argument for laboratory study, but one for field study. There are but few subjects which have suffered more from the preponderating influence of the laboratory.

To be sure, it may require more time to study in the field than if one collects specimens only, but it is economical in the long run. There are, of course, certain phases of more indirect observation which can be done best in the study or laboratory, but at present, field study, as contrasted with collecting, is a phase of effort urgently needing emphasis.

The processes of observation and field study and note taking are so intimately related that taking notes becomes one of the essential parts of careful observation. This is also one of the most difficult habits to acquire. The beginner is inclined to write them up, especially field notes, in the evening after his return from the field. Such notes are generally brief, lack details, and are usually of little value. Therefore the safest course to pursue is to describe fully whatever seems of value, then to go over these facts again and by further observations increase the number of items noted several times. These observations should be recorded as soon as made, for

generally the lack of notes means a lack of detailed observation. Some observations can be made only at long intervals, even of many years, others only with the return of another cycle of behavior, or of another season, and still others cannot be repeated. It is such considerations as these which emphasize the need of pursuing the safest course and recording instantly and fully all observations when made. An excess of notes is of very rare occurrence. In the effort to write carefully worded notes one has a very important check upon the tendency toward hasty observation, because such a description requires one to think over the observation before it can be expressed. This deliberation is thus made at the time when reobservation can be made to the best advantage, and calls attention to the weak points to which special consideration may perhaps be given a moment later, and thus affords a chance to complete the observation. Comstock (Insect Life, 1897, p. 323) has well summed up the taking of notes as follows: "Fill your notebook with descriptions, but digest them carefully, sifting out for publication only those that exhaustive study and repeated observation prove to be valuable. In making observations be sure you are right and then look again." And again as Van Hise (Science, N. S., Vol. XVI, p. 326) has said, "The difference between bad observation and good observation is that the former is erroneous; the latter is incomplete."

Notes are generally taken in one of two forms, in a book or on loose slips of paper or cards (Hop-

kins, 1893; Sanderson, 1904). It seems to be very generally agreed that if a book is used it should be of small size, of about 4 x 6 inches, so that it may be conveniently carried in the pocket. For a permanent record such books are a great convenience when once indexed. But when using such notes, while preparing a report, they are not so convenient as the note slips, unless one limits such a report to the form of a narrative. About ten years ago the writer began using a form of notebook in which an aluminum cover held the loose note slips. Thus while in the field one has the advantage of a book with a firm writing surface, and also that of the loose-leaf plan. This form of cover is now used by a number of field naturalists. The disadvantage of the slips not being bound might be remedied in part by using some form of punched slips which are convenient for binding.

Each one must decide for himself which form of recording notes answers his needs most satisfactorily. There are advantages in uniformity, but with the variable nature of work, it is sometimes very convenient to use both methods of recording.

Some students have no method of recording their observations or reflections upon their lines of interest. This seems to be unwise and suggests a method of business without bookkeeping. The efficiency of some students is greater than that of others, not so much because they possess superior mental ability, but because they have superior methods of preserving whatever useful ideas occur to them, while the others,

from their lack of records, have no cumulative store upon which to draw. This is an important form of capital. Note keeping is readily seen to consist not only of observations, but also of suggestions, inferences, conclusions, and reflections of any kind which will facilitate methods of work and the interpretation of the facts.

In describing environments, it is desirable to use the same general method for different localities so that the descriptions may be comparable and show some degree of standardization. This method has been found very useful in taxonomic studies and has similar advantages here. A brief general statement of the most conspicuous features may precede, and be followed by detailed descriptions. The order may well vary with individual workers, but a uniform method is desirable throughout any single piece of work and has obvious advantages. Thus one practical plan applied to a forest habitat is, to describe the substratum, the soil, rock, etc., then the forest litter of organic débris, then the boles of the trees and the forest crown and its character, and finally the operation of those agencies which are causing changes in the forest and which will perpetuate or change it in the future. No practical forester would be content to shut his eyes to the future crop of wood, and in the study of animal habitats we must not be content to rest below such a commercial standard. To some this seems very theoretical, and yet a farmer who counts upon a crop in five months, or a forester, in fifty years, is not so branded, and

the ecologist need have no fear in using such practical methods. In other words, we should consider the future stages of the developing habitat and learn to perceive the evidences which show in which direction development or change is taking place; or to determine the "orderly sequence of external nature." Not only should the future be considered, but we should strive also to read the record backward and interpret the past in terms of processes now in operation. In this respect the point of view of the geologist who interprets the past in terms of present processes may well merit our attention. To understand our habitats they must be studied not only in their length and breadth, but also in depth past and future — as they have all three dimensions.

The preceding remarks bear equally well upon observations of the activities of animals in nature, on account of the absence of controlled conditions, for these methods have almost as much significance as the study of the environments themselves; and equally careful observations and descriptions are essential, if the detailed processes of animal activities and their transformations are to be recorded.

An experienced naturalist finds that from year to year the amount of notes which he takes increases rapidly, and in a very direct ratio to the progress which he makes in his study. Good note taking is not a passive process, but one which calls for an alert mind. The prolonged interest which is necessary to secure detailed observations implies such a frame of mind.

Every one soon tires of any subject unless new features are constantly being discovered.

In the description of the associations in any given habitat, the problem is much simplified if one has a clear idea of dominance, knows how to recognize it, and understands some of its main implications. The dominant forms are the most common and powerful individuals in the association. They may or may not be the most conspicuous, from a superficial view. Conspicuousness may depend upon size, but dominance refers to large absolute numbers and to influence exerted. We may profitably compare an association of animals in a given habitat to a play upon the stage. The environment corresponds to the stage. The dominant members of the association correspond to the leading characters, the secondary species, always present, to the essential but subordinate characters. The individual animals adjust themselves to one another, especially to the dominant forms, and to the environment, as the personalities in the play adjust themselves to the dominant characters, to one another, and to the environment. In both groups some individuals are dominant, some used and useful, some are tolerated, others pick up the crumbs, still others are predatory or parasitic, and all must be mutually adjusted to one another and to the environment.

The number of dominant species within an association is relatively limited, a fact which holds for both plants and animals. A knowledge of perhaps 200 or 300 species of animals (and 150 plants)

will enable one to work advantageously in many localities (as in the state of Illinois). Of this number perhaps not more than about one half or one third can be considered dominant. Every one who has tried to make extensive local lists of species knows that it requires many years of collecting to secure a large number of species. These rare species are generally of quite minor importance ecologically. Considerations of this character should be encouraging to those who may be intimidated by the idea of large numbers of species. Then, of course, it should be remembered that there are many aspects of ecological work which do not meet with this variety of animals.

IV. THE COLLECTION, PRESERVATION AND DETERMINATION OF SPECIMENS

ECOLOGICAL study does not end with collecting specimens, and it may not begin there. The importance of collecting and preserving specimens will vary with the phase of ecological study considered. In the field study of behavior of a single species there may be almost no collecting of animals but much collecting of notes; but if one is devoted primarily to the recognition and study of the composition of associations and their interrelations, much collecting will have to be done. Also, when studying the ecological relations of some taxonomic unit, as in aggregate ecology, the number of associates is so large that one must do rather extensive collecting. But even the exhaustive study of the behavior of any single species will necessitate considerable collecting. The necessity for this has been shown by Forbes (1880, The Food of Fishes, p. 20) as follows: "If one wishes to become acquainted with the black bass, for example, he will learn but little if he limits himself to that species. He must evidently study also the species upon which it depends for its existence, and the various conditions upon which these depend. He must likewise study the species with which it comes in competition, and the entire system

49

E

of conditions affecting their prosperity. Leaving out any of these, he is like one who undertakes to make out the construction of a watch, but overlooks one wheel; and by the time he has studied all these sufficiently, he will find that he has run through the whole complicated mechanism of the aquatic life of the locality, both animal and vegetable, of which his species forms but a single element."

Collecting is an important means of ecological study. This is particularly true in the early stages of such study, but as the student becomes familiar with species and comes to know many of them at sight, less collecting will be necessary, except in the case of very small species and in those studies which depend upon the total catch as a means of securing data, as, for example, the case of plankton organisms. On account of the large number of species, very few students will be able to determine them at sight, but this does not disqualify a student for beginning ecological study. The greatest aid in handling such a varied population is a numbering of the individuals, or lots of specimens, consecutively and recording the full data for them in the notebook. The question arises at once as to how many specimens are to be assigned to one number. No rigid rule can be followed, but in general it is safe to assign a single number to all specimens which agree in all the fundamental data, as date, place of capture, and exact habitat. And for my own part I number all individuals taken, upon which any special observations are made, as when a Phymatid is taken with a dy-

ing or dead honeybee, or a dragon fly is taken from the web of an Argiope. In this way the confusion which is particularly liable to creep into one's work, where he deals with a large number of species, and before familiarity with them is acquired, may be reduced to the minimum. For small animals I have found useful a very liberal use of vials, into which field numbers, corresponding to numbers in the field notes, are placed immediately upon capture of the specimens, and not minutes or hours later when the vials have become mixed, and recollection is less sharp. Specimens which have been thoroughly numbered may thus be sent to specialists for determination. This method uses up many numbers, but, fortunately, the supply is unlimited, and it gives greater precision to one's notes, and encourages detailed observations on individual animals.

In the eyes of many the determination of specimens is such a formidable task that they are at once repelled from any subject which involves numerous species. But as we have previously remarked, there are phases of ecological study which involve only a minimum amount of such work. On the other hand, one may readily have an undue fear of numerous species, but no one can doubt that the smaller number of species found upon mountains or in the far north gives to a beginner certain advantages for study. But if one's studies are confined to the more restricted habitats, the number of species involved is comparable to the more favored localities mentioned.

An accurately determined series of specimens, conveniently arranged, will be an important aid in one's studies. Two forms of arrangement of such determined series are very helpful; one being synoptic or systematically arranged, and the other ecologically, by associations or by a topical arrangement in harmony with the subjects being investigated. With the use of such series and proper caution, aided by the best keys in the literature, one may hope to make many of his own determinations and thus economize his time.

There are many ways to secure the initial series of determined specimens, and some of these are the following: Our governmental departments, both national and state, and many of our large museums, universities, and academies, have numerous experts who are quite willing and even eager to aid earnest students who wish to have specimens determined. Then, in addition, there are many expert amateurs who are equally liberal, so that when all the sources of aid are considered, the list becomes a surprisingly long one. This is the fact that should be called to mind when considering large numbers of species. A student therefore does not need to work alone, but may have the cooperation of a large number of able and willing collaborators. Naturally we turn for aid to our United States National Museum as one of the first sources of assistance, to the Smithsonian Institution, and to the various scientific departments of the U.S. Department of Agriculture, particularly to the Bureaus of Plant Industry,

Biological Survey, and Entomology. These sources alone are able to determine almost any reasonable series of specimens, particularly if they are well preserved. Arrangements for such determinations can probably be made by addressing the proper authorities.

The museums of our larger cities, as the American Museum of Natural History of New York, the Carnegie Museum at Pittsburgh, the Field Museum of Chicago, and many smaller state and local museums are able to give very efficient aid in this line. Other local institutions are the State Universities and Experiment Stations, and the local natural history surveys, which often exist under the guise of a geological or agricultural organization. Frequently they are qualified and willing to do this work.

In very difficult cases it may be necessary to have recourse to Cassell's Naturalist's Universal Directory (Boston, 1905), in order to find the address of some specialist in a foreign land, who can help, but generally Americans are the best informed upon their own fauna.

Supplementary to, and in some cases a necessary substitute for, a reference series of authentically determined specimens, is one which the student is able to name for himself, by the study of the literature. Without some special training this may become dangerous ground to tread upon, but every now and then some young student begins in this way and develops such care in determining his own collections, that the method cannot be wholly

condemned. Such work in itself has fascinations, and one may easily occupy all one's time with it. From the ecological standpoint to stop with determinations only would be like acquiring a certain vocabulary, and stopping before learning how to use the language. Ecological work aims to use the names of species as the most concise method of referring to kinds of animals whose interrelations are to be described and interpreted. Taxonomy is the tool.

V. REFERENCES TO SCIENTIFIC TECHNIQUE

- 1. The Scientific Method.
- 2. Directions for Collecting and Preserving Specimens, Photographing, Surveying, and Other Phases of Technique.
- The Preparation of Papers for Publication and Proof Reading.

1. The Scientific Method

CHAMBERLIN, T. C.

1897. The Method of Multiple Working Hypotheses. Jour. Geol., Vol. V, pp. 837-848.

1906. The Method of the Earth Sciences. Pop. Sci. Mo., Vol. LXVI, pp. 66-75. Inter. Cong. of Arts and Sciences, St. Louis, Vol. IV, pp. 477-487.

Very important papers and worthy of careful study.

GILBERT, G. K.

1886. The Inculcation of Scientific Method by Example, with an Illustration drawn from the Quaternary Geology of Utah. Amer. Jour. Sci., (3), Vol. XXXI, pp. 284-299.

1887. Special Processes of Research. Amer. Jour. Sci., (3), Vol. XXXIII, pp. 452-473.

MELDOLA, R.

1895. The Speculative Method in Entomology. Trans. Ent. Soc., London, 1895, pp. XLVIII-LXXIII.

VAN HISE, C. R.

1902. The Training and Work of a Geologist. Science, N. S., Vol. XVI, pp. 321-334.

KEYES, C. R.

1898. The Genetic Classification of Geological Phenomena. Jour. Geol., Vol. VI, pp. 809-815.

> Valuable for its discussion of the criteria used in geneticstudies.

VAN HISE, C. R.

1904. The Problems of Geology. Jour. Geol., Vol. XII, pp. 589–616; Inter. Cong. Arts and Sciences, St. Louis, Vol. IV, pp. 525–548. 1906.

An excellent discussion of the energy, agent, and process method of investigation. I have seen no similar discussion applied to biological or zoölogical subjects.

Boas, F.

1896. The Limitations of the Comparative Method of Anthropology. Science, N. S., Vol. IV, pp. 901-908.

A suggestive paper for the student of ecology who uses the comparative method in his own work.

1904. The History of Anthropology. Science, N. S., Vol. XX, pp. 513-524.

Application of the genetic and historical method to the study of man.

MILL, J. S.

1881. A System of Logic, Ratiocinative and Inductive:
Being a Connected View of the Principles of Evidence and the Methods of Scientific Investigation.
Eighth Edition. pp. 659. New York.

PEARSON, K.

1900. The Grammar of Science. Second Edition. pp. 548.
London.

JEVONS, S.

1879. Principles of Science. Third Edition. pp. 786.
London.

Certain chapters are of special interest.

CRAMER, F.

1896. The Method of Darwin. A Study in Scientific Method. pp. 232. Chicago.

MACDOUGAL, ROBT.

1905. On the Discrimination of Critical and Creative Attitudes. Jour. Philos. Psy. and Sci. Methods, Vol. II, pp. 287–293.

LEBON, G.

1898. The Life History of Scientific Ideas. Pop. Sci. Mo., Vol. LII, pp. 251-254.

2. Directions for Collecting and Preserving Specimens, Photographing, Surveying, and Other Phases of Technique

There is such an abundance of literature on the technique of collecting and preserving specimens, and so much of it can easily be secured by any earnest student, that space will not be taken to discuss these subjects in detail. Reference will simply be made to the main convenient sources of information. It should perhaps be mentioned that very few of these papers have been especially prepared from the standpoint of the animal ecologist. The student must select and devise his methods from all available sources.

I have included in this list a few references on the subject of camping, photography, and the use of instruments needed in the determination of the physical features of the environment. A few miscellaneous papers which are suggestive on methods of technique are also added.

MANY AUTHORS.

1891–1899. Bulletin 39, U. S. National Museum. Parts A to O.

Contain directions for collecting and preserving a great variety of animals, including marine animals, mollusks, insects, spiders, myriapods, reptiles, amphibians, birds, birds' eggs and nests, mammals, etc.

ANONYMOUS.

Manual for Army Cooks. pp. 306. Washington. The Manual used by the cooks in the U. S. Army. It includes chapters on camp cooking, a subject of much importance in certain ecological surveys.

1905. Terms used in Forestry and Logging. Bull. 61, Bureau of Forestry, U. S. Dept. Agr. pp. 53.
Useful in the descriptions of forest conditions.

1904. Instructions to Field Parties and Descriptions of Soil
Types. Bureau of Soils, U. S. Dept. Agr. pp. 198.
Useful in the description of soils in the study of subterranean animals.

BANKS, N.

1907. A "Census of Four Square Feet." Science, N. S., Vol. XXVI, p. 637. A criticism of McAtee (1907).

1909. Directions for Collecting and Preserving Insects. Bull.
67, U. S. Nat. Mus. pp. 135.

An excellent manual. Should be in the hands of every student of insects.

Bretscher, K.

1902. Beobachtung über die Oligochaeten der Schweiz, VI. Folge. Rev. Suisse de Zoöl., Ann. Soc. Zoöl. Suisse et du Mus. d'His. Nat. de Geneve, Tome 10, pp. (1-29).

1904. Die xerophilen Enchytraeiden der Schweiz. Biol, Centralbl., Bd. XXIV, pp. 501-513.
Quantitative studies of earthworms in the soil.

BRUNNER, J.

1912. Tracks and Tracking. pp. 219. New York. Outing Publishing Co.

An illustrated guide for the identification of mammal

BURNS, F. L.

1901. A Sectional Bird Census. Wilson Bulletin, N. S., Vol. VIII, pp. 84-103.

A quantitative study of the birds found breeding on an area of one square mile. Other similar studies should be made.

CHAPMAN, F. M.

1900. Bird Studies with a Camera. With Introductory
Chapters on the Outfit and Methods of the Bird
Photographer. pp. 218. New York.

The title clearly indicates the character of this book.

COMSTOCK, J. H.

1897. Insect Life. pp. 349. New York. Directions for the study of insects.

CLEMENTS, F. E.

 Research Methods in Ecology. pp. 334. Lincoln, Nebraska.

Important for methods of study in plant ecology, partly also applicable to animals; photography, and instruments for the study of environments.

DAHL, F.

1901. Was ist ein Experiment, was Statistik in der Ethologie?
Biol. Centralbl., Bd. XXI, pp. 675-681.

1903. Winke für ein wissenschaftlicher Sammeln von Thieren. Sitzungs-Ber. der Gesell. naturfor. Freunde zu Berlin. Jahrg. 1903, pp. 444–475.

This contains, in addition to its suggestions on collecting, an interesting outline or classification of animal habitats (Cf. also Enderlein, 1908, pp. 72-77). This is not a genetic classification. Dahl's list of habitats will prove very suggestive to the student

who wishes to develop the genetic system of classification. Ultimately we must, of course, develop the latter system.

1904. Kurze Anleitung zum wissenschaftlichen Sammeln und zum Conservieren von Thieren. pp. 59. Jena. An enlarged edition of the preceding paper.

DAVENPORT, C. B.

1904. Statistical Variation with Special Reference to Biological Variation. Second, Revised Edition. pp. 223.
New York.

FORBES, S. A.

1907. An Ornithological Cross-Section of Illinois in Autumn. Bull. Ill. State Lab. Nat. His., Vol. VII, pp. 305–335.

1908. The Mid-Summer Bird Life of Illinois: A Statistical Study. Amer. Nat., Vol. XLII, pp. 505-519.

GIBSON, W. H.

1905. Camp Life in the Woods and the Tricks of Trapping and Trap Making. pp. 300. New York.

A book for boys, but not without value to the older student of live animals.

FLAHAULT, C., and SCHRÖTER, C.

1910. Phytogeographical Nomenclature. Reports and Propositions, III^o Cong. Inter. de Bot. 1910. Bruxelles. pp. 28. Zurich.

A very valuable discussion of ecological nomenclature for plants. Defines the use of such terms as biology, ecology, habitat, association, formation, etc. It is very desirable that the plant and animal ecologists coöperate as much as possible in this subject.

HENSEN, V.

1887. Ueber die Bestimmung des Plankton's oder des in Meere treibenden Materials an Pflanzen und Thieren; nebst Anhang. Fünfter Ber. der Komm. zur wissensch. Untersuch. d. deutschen Meere in Kiel für die Jahre 1882 bis 1886, pp. 1-107, III-XVIII, Berlin.

This appears to be the original account of quantitative studies as applied to plants and animals of an association. These methods have been extended to the sea bottom by Petersen, to fresh water by many students, to land animals mainly by Dahl, and in recent years to plants by Clements and others.

HERRICK, C. L.

1905. Home Life of Wild Birds. Revised Edition. pp. 255. New York.

> Very valuable for suggestions on the study of live birds and how to photograph them.

HOPKINS, A. D.

1893. Note and Record Keeping for the Economic Entomologist. U. S. Dept. Agr., Div. Ent., Insect Life, Vol. VI, pp. 103-108.

JOB. H. K.

1910. How to Study Birds. A Practical Guide for Amateur Bird-Lovers and Camera-Hunters. pp. 272. New York. Outing Publishing Co.

Intended primarily for beginners in bird study, but contains valuable practical advice on methods of studying and photographing live birds which will aid the ecologist. Consult also Kearton (1907), Chapman (1900), and Herrick (1905).

KEARTON, R.

1907. Wild Life at Home: How to Study and Photograph It. New and Revised Edition. pp. 204. London.

KEPHART, H.

The Book of Camping and Woodcraft. pp. 331. Fifth 1912. Edition. Outing Publishing Co.

> This is the best all-round book on the technique of camping and living in the wilderness which I have seen. It includes direction for selecting outfits.

making camps, cookery, pests in the woods, blazes and survey lines, rations, emergency foods, getting lost, accidents, etc.

KNAUTHE, K.

1907. Das Süsswasser, chemische, biologische, und bakteriologische Untersuchungsmethoden unter besonderer Berücksichtigung der Biologie und der fischereiwirtschaftlichen Praxis. pp. 663. Neudamm.

> A very important work on the technique of fresh water biology.

LEE, A. B.

1900. The Microscopist's Vade Mecum. A Handbook on the Methods of Microscopic Anatomy. Fifth Edition. pp. 532. Phila.

> Very useful for methods of preserving delicate animals, and those in which the detailed structure of the animal must be studied.

LIVINGSTON, B. E.

1906. The Relation of Desert Plants to Soil Moisture and to Evaporation. Carnegie Inst. Pub. No. 50. pp. 78. Methods of determination of moisture content of the soil and the air.

McAtee, W. L.

1907. Census of Four Square Feet. Science, N. S., Vol. XXVI, pp. 447-449.

A quantitative study of the species of invertebrates and seeds found on the forest floor and on a meadow.

1912. Methods of Estimating the Contents of Bird Stomachs. The Auk, Vol. XXIX, pp. 449-464.

1912. The Experimental Method of Testing the Efficiency of Warning and Cryptic Coloration in Protecting Animals from their Enemies. Proc. Acad. Nat. Sci. Phila., 1912, pp. 281-364.

An important critical study of the value of feeding experiments, conducted in captivity, as a method of determining normal food habits. The method is strongly condemned. Valuable series of references.

NEUMAYER, G. VON.

1906. Anleitung zu Wissenschaftlichen Beobachtungen auf Reisen. Dritte Auflage, Bd. 1, pp. 842; Bd. 2, pp. 880. Hanover.

A very important work, particularly for the traveling naturalist. Chapters by specialists, valuable references on collecting natural history specimens, and other phases of scientific exploration.

PEARL, R.

1911. Biometric Ideas and Methods in Biology; their Significance and Limitations. Scientia, Vol. X, pp. 101-119.

PETERSEN, C. G. JOH., and JENSEN, P. B.

1911. Valuation of the Sea. 1. Animal Life of the Sea-Bottom, its Food and Quantity. Rep. of the Danish Biol. Sta. to the Board of Agriculture, Vol. XX. pp. 76. Translated from Fiskeri-Beretning for 1910. Copenhagen.

Methods and results of a quantitative study of animals on the sea-bottom. A very important paper. Descriptions and figures of the apparatus used.

REIGHARD, J.

1908. Methods of Studying the Habits of Fishes, with an Account of the Breeding Habits of the Horned Dace. U. S. Bur. of Fisheries Bull., Vol. XXVIII, pp. 1111-1136.

1908. The Photography of Aquatic Animals in their Natural Environment. Bull. U. S. Bur. of Fisheries, Vol. XXVIII, pp. 41-68.

These papers also contain references to others on the habits of fishes.

KING, L. A. L., and RUSSELL, E. S.

1909. A Method for the Study of the Animal Ecology of the

Shore. Proc. Roy. Phys. Soc. of Edinburgh, Vol. XVII, No. 6, pp. 225-253.

SANDERSON, E. D.

1904. A Card-Index System for Entomological Records.
 U. S. Dept. Agr., Div. Ent., Bull. 46, pp. 26-34.
 Contains references to other methods of recording notes.

SIMPSON, C. B.

1903. Photographing Nets of Hydropsyche. Proc. Ent. Soc. Wash., Vol. V, pp. 93-95.

SUMNER, F. B.

1910. An Intensive Study of the Fauna and Flora of a Restricted Area of the Sea Bottom. Bull. U. S. Bur. of Fisheries, Vol. XXVIII, pp. 1225–1263.

A study on our coast along lines similar to those of C. G. J. Petersen's "Det Videnskabelige Udbytte af Kanonbaaden 'Hauchs' Togter I de Danske Have Indenfor Skagen I Aarene" 1883–1886. 1893. pp. 464. Atlas. Copenhagen.

TRANSEAU, E. N.

1908. The Relation of Plant Societies to Evaporation. Bot. Gaz., Vol. XLV, pp. 217-231.

Methods of studying the relative humidity of the air in various plant associations, also applicable to certain studies of animals.

WAINWRIGHT, D. B.

1905. A Plane Table Manual. Department of Commerce and Labor, Report U. S. Coast and Geodetic Survey for 1905. Appendix No. 7, pp. 295-341.

> In making local studies the plane table may be very helpful.

WRIGHT, A. H.

1907. A Graphic Method of Correlating Fish Environment and Distribution. Amer. Nat., Vol. XLI, pp. 351-354.

WILSON, H. M.

1905. Topographical Surveying. Second Edition. New York.

Directions for camping, emergency surgery, photography, etc., pp. 811-884.

In concluding this list of references I would suggest to the student the desirability of securing the following catalogues or lists of publications. A glance at the lists in this volume will show that a surprisingly large number of the papers or works are governmental publications, many of which have long been out of print, but many may still be secured from the different departments or from the Superintendent of Documents at Washington, D.C.

- 71. U. S. Geological Survey. List of Publications, including maps. Washington, D.C.
- ,2. Superintendent of Documents. Lists of publications of the U. S. Department of Agriculture. Washington, D.C.
- 3. Smithsonian Institution. List of publications. Washington, D.C.
- U. S. National Museum. List of publications. Washington, D.C.
- 5. U. S. Bureau of Fisheries (formerly U. S. Fish Commission). List of publications. Washington, D.C.
- 76. For list of dealers in second-hand books see Banks' Bull. 81, U. S. National Museum, pp. 117-118. This is one of the best methods of securing many publications which are out of print.

3. The Preparation of Papers for Publication and on Proof Reading

The preparation of papers for publication is a practical phase of study and an art, or form of technique, about which the zoölogical student is liable to hear but little. There may be a great economy of effort, and much time saved, if early in

his work the student realizes the need of cultivating the habit of preparing all manuscripts in a form suitable for publication. While there is much variation in details, yet within certain limits there is a certain amount of standardization which should become habitual. Departures from such a standard necessitate much loss of time which must be devoted to revisions and corrections. One may work for years and fail to realize this fact, until he attempts to adjust his habits of writing to the requirements of the editors of scientific publications. The following references are intended to cover the main aspects of the preparation of manuscripts and the reading of proof.

LEWES, GEORGE HENRY (Edited by F. N. Scott).

1891. The Principles of Success in Literature. pp. 163. Boston. Allyn and Bacon.

A very sane little book on writing, a subject on which it is difficult to receive and apply advice.

WENDELL, B.

1899. English Composition. pp. 316. New York.

FERNALD, J. C.

1896. English Synonyms and Antonyms with Notes on the Correct Use of Prepositions. Tenth Edition. pp. 564. New York.

1904. Connectives of English Speech. The Correct Usage of Prepositions, Conjunctions, Relative Pronouns and Adverbs Explained and Illustrated. pp. 324. New York.

ALLBUTT, T. C.

1905. Notes on the Composition of Scientific Papers. pp.164. London. Macmillan Company.

This book is by an experienced medical editor and contains many practical suggestions.

RICKARD, T. A.

1910. A Guide to Technical Writing. Second Edition. pp. 172. San Francisco. Mining and Scientific Press. Intended primarily for writers on mining, and yet it contains much that is useful and suggestive to zoologists particularly the chapters on the need of simplicity in the language of science, and on the value of standardization.

WARMAN, P. C.

1903. A Plea for Better English in Science. Science, N. S., Vol. XVIII, pp. 563-568. Reprinted with revision, 1910. Washington.

DAVIS, W. M.

- 1911. The Disciplinary Value of Geography. Pop. Sci. Mo., Vol. LXXVIII, pp. 105-119, 223-240.
 - An illuminating paper on the "art of presentation" of scientific results in oral and written form.
- 1909. The Systematic Description of Land Forms. Geogr. Jour., Vol. XXXIV, pp. 300-318.
- 1909. Glacial Erosion in North Wales. Quart. Jour. Geol. Soc., Vol. LXV, pp. 281-350.
- 1910. Experiments in Geographical Description. Bull. Amer. Geogr. Soc., Vol. XLII, pp. 401-435.
- 1911. The Colorado Front Range. A Study in Physiographic Presentation. Ann. Associa. Amer. Geogr., Vol. I, pp. 21–83.
 - The four preceding papers are in many respects models of presentation. They exemplify the process method applied to regions, a phase of much importance in certain ecologic studies, particularly ecological surveys. The last two papers are rather detailed applications of the same ideas. A very profitable study may be made of the method of presentation in these papers.

DEVINNE, T. L.

1902. The Practice of Typography. Correct Composition.

A Treatise on Spelling, Abbreviations, the Compounding and Division of Words, the Proper Use of Figures and Numerals, Italic and Capital Letters, Notes, etc., with Observations on Punctuation and Proof-reading. Second Edition. pp. 476. New York.

Perhaps the highest American authority on all the subjects discussed.

WOOD, G. M.

1909. Suggestions to Authors of Papers Submitted for Publication by the United States Geological Survey with Directions to Typewriters. U. S. Geol. Survey. pp. 50. Washington.

Can be secured gratis from the Survey.

ANONYMOUS.

1903. Government Printing Office Manual of Style for Use in Composition and Proof Reading. pp. 191. Washington, D.C.

VAUX, C. B.

How to Prepare a Paper for Publication. Bull. No. 4.
 Wistar Inst. Anat. and Biology. pp. 20. Phila.

1910. Style Brief. A Guide for Authors in Preparing Copy and Correcting Proof of Professional Papers and for the Use of Editors and Printer, adopted as the Standard of the Journals Published by the Wistar Institute of Anatomy and Biology, Philadelphia. pp. 32. First Edition. Baltimore.

The Wistar Institute publishes the "Journal of Experimental Zoölogy," which is devoted to "original researches of an experimental or analytical nature" on many branches of zoölogy, including ecology and general physiology. The "Style Brief" can be secured from the Institute.

REFERENCES TO SCIENTIFIC TECHNIQUE 69

ORCUTT, W. D.

1912. The Writer's Desk Book. pp. 184. New York. F. A. Stokes Co.

A useful handbook on punctuation, capitalization, spelling, abbreviations, numerals, etc., and with an appendix on weights and measures.

WOOLLEY, E. C.

1907. Handbook of Composition. A Compendium of Rules Regarding Good English, Grammar, Sentence Structure, Paragraphing, Manuscript Arrangement, Punctuation, Spelling, Essay Writing and Letter Writing. pp. 239. Boston.

VI. IMPORTANT SOURCES OF INFORMATION ON THE LIFE HISTORIES OF INSECTS AND ALLIED INVERTEBRATES

INSECTS are to-day one of the dominant forms of life and are present in almost every large animal association or habitat. They therefore form an important element in a large number of ecological studies. And although facts of ecological significance have been accumulating for many years they are so widely scattered that to find them when needed is quite a serious problem. To aid in such a search the following references are given. should be remembered that spiders, mites, and myriapods are commonly included in entomological literature and are therefore included in this list. The list is not intended as a substitute for the more elaborate sources such as the Zoölogical Record and similar standard works to be found in large libraries, but it includes publications that are more likely to be within the grasp of teachers and students not located at library centers. Many of these are public documents, and even if out of print, can easily be secured from second-hand dealers.

A student who has access to large libraries will find the following paper very valuable in suggestions as to the methods of finding the literature on many general zoölogical subjects.

MINOT, C. S.

1896. Bibliography. A Study of Resources, pp. 149–168.
Biol. Lectures, Wood's Holl, 1895. Boston.

(Alphabetically arranged.)

ALDRICH, J. M.

1905. A Catalogue of North American Diptera. Smithsonian Misc. Coll., Vol. XLVI, No. 1444. pp. 680. Contains an extensive bibliography on flies.

ANONYMOUS.

1906. Catalogue of Publications Relating to Entomology in the Library of the U. S. Department of Agriculture. Library Bulletin 55. pp. 562. Washington.

BANKS, N.

1892. A Synopsis, Catalogue, and Bibliography of the Neuropteroid Insects of Temperate North America.

Trans. Amer. Ent. Soc., Vol. XIX, pp. 327-373.

1898-1905. Bibliography of the More Important Contributions to American Economic Entomology, Parts VI, VII, and VIII. U. S. Department of Agriculture, Bureau of Entomology.

A continuation of the work begun by Henshaw (1889–1896).

71900. A List of Works on North American Entomology. U. S. Dept. Agr., Div. Ent., Bull. No. 24 (N. S.). pp. 95.

1902. An Index to Bulletins Nos. 1-30 (N. S.), (1896–1901), of the Division of Ent. U. S. Dept. Agr., Div. Ent., Bull. No. 36 (N.S.). pp. 64.

1910. A List of Works on North American Entomology. U. S. Dept. Agr., Div. Ent., Bull. 81. pp. 120.

This and the preceding edition (1900) form a very useful index to the systematic literature of insects, spiders, myriapods, etc.

1910. Catalogue of the Nearctic Hemiptera-Heteroptera. Amer. Ent. Soc. pp. 103. Philadelphia.

7 1910. Catalogue of Nearctic Spiders. U. S. Nat. Mus., Bull. 72. pp. 80.

> In the absence of special bibliographies these catalogues are the most convenient avenue to the literature.

BETHUNE, C. J. S.

1900. General Index to the Thirty Annual Reports of the Entomological Society of Ontario, 1870-1899. pp.
76. Ontario Dept. Agr.

BEUTENMÜLLER, W.

1891. Bibliographical Catalogue of the Described Transformations of North American Coleoptera. Jour. N. Y. Micros. Soc., Vol. VII, pp. 1-52.

1890. Preliminary Catalogue of the Described Transformations of the Odonata of the World, pp. 165-179. In Lamborn, R. H., Dragonflies vs. Mosquitoes. New York.

1893. On the Food Habits of the North American Rhynchophora. Jour. N. Y. Ent. Soc., Vol. I, pp. 36-43, 80-88.

1896. Food-Habits of North American Cerambycidæ. Jour. N. Y. Ent. Soc., Vol. IV, pp. 73-81.

CHITTENDEN, F. H.

1893. Note on the Food Habits of Some Species of Chrysomelidæ. Proc. Ent. Soc. Wash., Vol. II, pp. 261-267.

>1897. General Index to the Seven Volumes of Insect Life, 1888-1895. U. S. Dept. Agr., Div. Ent.

COMMISSIONER OF AGRICULTURE.

1876. The General Index of the Agricultural Reports of the Patent Office for 1837–1861, and of the Department of Agriculture for 1862–1876. Washington.

COMSTOCK, J. H.

1879. Report upon Cotton Insects. U.S. Dept. Agr. pp. 511.

This report, like those of the U.S. Entomological Com-

mission, gives very full accounts of the habits and life histories of certain species and gives particular attention to their predaceous and parasitic enemies. The predaceous insects are seldom given as detailed study as the vegetable-feeding kinds.

COQUILLETT, D. W.

1881. Larvæ of Lepidoptera. Tenth Ann. Rep. State Ent. Ill., pp. 145-186.

Descriptions, figures, and keys to many common larvæ.

CRESSON, E. T.

Synopsis of the Hymenoptera of America, North of Mexico. Trans. Amer. Ent. Soc., Supplem. Vol., 1887, Pt. 2. Catalogue of Species and Bibliography, pp. 155-350. Philadelphia.

CURRIE, R. P., and CAUDELL, A. N.

1911. An Index to Circulars 1 to 100 (Second Series) of the Bureau of Entomology. U. S. Dept. Agr., Bur. Ent., Circular No. 100. pp. 49.

> The circulars contain a large amount of information on life histories of insects.

DIMMOCK, G., and KNAB, F.

1904. Early Stages of Carabidæ. Bull. No. 1, Springfield Mus. Nat. Hist. pp. 55. Springfield, Mass.

Dodge, C. R.

1888. The Life and Entomological Work of the Late Townend Glover. U. S. Dept. Agric., Div. Ent., Bull. No. 18 (O. S.). pp. 68.

DYAR, H. G.

1894. A Classification of Lepidopterous Larvæ. Ann. N. Y. Acad. of Sci., Vol. VIII, pp. 194-232.

, EDWARDS, H.

1889. Bibliographical Catalogue of the Described Transformations of North American Lepidoptera. U. S. Nat. Mus., Bull. 35. pp. 147.

>FELT, E. P.

Insects Affecting Park and Woodland Trees. Mem.
 N. Y. State Mus., Vol. I, pp. 1-332, a435-a459, 1905; Vol. II, pp. 333-877, 1906.

Excellently illustrated, and with numerous references.

This report and Packard's Forest Insects form an excellent guide to the life histories and literature of forest insects.

>1899. Memorial of Life and Entomologic Work of Joseph Albert Lintner, Ph. D. N. Y. State Mus., Bull. 24, Vol. V, pp. 303-611.

> Contains an index to Lintner's thirteen reports as State Entomologist of New York. These reports contain rather full references and good summaries of life histories.

FOLSOM, J. W.

1906. Entomology with Special Reference to its Biological and Economic Aspects. pp. 485. Philadelphia.

A very useful bibliography is given on pp. 409–466.

FORBES, S. A.

1885. General Indexes to the First Twelve Reports of the State Entomologists of Illinois. App. to Fourteenth Rep. State Ent. Ill. pp. 120. Springfield.

1909. Contents and Index of the Reports of the State Entomologist of Illinois, XIII-XXIV. 1884-1908.
pp. 157. Office of State Entomologist.

FORBES, W. T. M.

1906. Field Tables of Lepidoptera. pp. 141. Worcester, Mass. Keys for the determination of larvæ.

1910. A Structural Study of Some Caterpillars. Ann. Ent. Soc. Amer., Vol. III, pp. 94-132.
 Contains a very useful bibliography (pp. 125-127).

FORBUSH, E. H., and FERNALD, C. H.

1896. The Gypsy Moth. Mass. Board Agr. pp. 495.

Also discusses predaceous and parasitic animals which prey upon the Gypsy Moth.

HART, C. A.

1895. On the Entomology of the Illinois River and Adjacent Waters. Bull. Ill. State Lab. Nat. Hist., Vol. IV, pp. 149-284.

Keys to immature stages of aquatic insects and many biological observations.

HENSHAW, S.

1887. The Entomological Writings of Dr. Alpheus Spring Packard. U. S. Dept. of Agr., Div. Ent., Bull. No. 16. pp. 49.

Biological observations.

71889-96. Bibliography of the More Important Contributions to American Economic Entomology, Parts I-V, and index. U. S. Dept. of Agr., Div. Ent.

Hubbard, H. G.

1885. Insects Affecting the Orange. U. S. Dept. Agr., Div. Ent. pp. 227.

JOHANNSEN, O. A.

1903, 1905. Aquatic Nematocerous Diptera. N. Y. State Mus., Bull. No. 68, pp. 328-448; Bull. No. 86, pp. 76-327.

Immature stages of several families are rather fully treated and valuable references on life histories given.

MACGILLIVRAY, A. D.

1903. Aquatic Chrysomelidæ and a Table of the Families of Coleopterous Larvæ. Bull. No. 68, N. Y. State Mus., pp. 288-331.

Gives references to the most important papers on the immature stages of beetles.

NEEDHAM, J. G., and BETTEN, C.

7 1901. Aquatic Insects in the Adirondacks. Bull. No. 47, N. Y. State Mus., pp. 383-612.

Keys to orders to immature aquatic insects; keys to Mayfly and dragon-fly nymphs.

NEEDHAM, J. G.

1903. Life Histories of Odonata, Suborder Zygoptera. Bull.
 No. 68, N. Y. State Mus., pp. 218-276.
 Keys to nymphs.

7 1905. Ephemeridæ. Bull. No. 86, N. Y. State Mus., pp. 17-59.

Keys to genera of adults and to nymphs.

1908. Report on the Entomologic Field Station Conducted at Old Forge, N. Y., in the Summer of 1905. Bull. No. 124, N. Y. State Mus., pp. 156-248.

Life histories of crane flies, Tipulidæ; table of larval habits, p. 239, and fish food.

OFFICE OF EXPERIMENT STATIONS, U. S. DEPT. AGRIC.

>1889. Experiment Station Record, Vol. I to date.

71903. General Index to Experiment Station Record, Vols. 1-12, 1889-1901, and to Exp. Sta. Bull. No. 2. pp. 671.

Useful for references to current literature on economic species, before they have appeared in the more slowly published bibliographies.

PACKARD, A. S.

71890. Forest Insects. U. S. Dept. Agr., Fifth Rep. U. S. Ent. Comm. pp. 957.

Almost an encyclopedia on forest insects, insects listed by food plants. Very useful.

PIERCE, W. D.

1907. On the Biologies of the Rhynchophora of North America. Ann. Rep. Neb. St. Bd. Agr., 1906-07, pp. 247-319.

This is an annotated list of breeding and food habits of the snout and bark beetles. References to the literature, index of plants and beetles. Very useful.

1908. A List of Parasites Known to Attack American Rhynchophora. Jour. Econ. Ent., Vol. I, pp. 380-396.

RILEY, C. V., PACKARD, A. S., and THOMAS, C.

1878. First Annual Report of the U.S. Entomological Com-

mission for the Year 1877, Relating to the Rocky Mountain Locust, etc. U. S. Geol. Surv. (Hayden). pp. 477.

Discusses predaceous and parasitic animals which prey upon the locust.

71880. Second Report of the U. S. Entomological Commission for the Years 1878 and 1879, Relating to the Rocky Mountain Locust, and the Western Cricket, etc. U. S. Dept. Interior. pp. 322.

Discusses predaceous and parasitic animals which prey upon the locust.

RILEY, C. V.

1880. Food Habits of the Longicorn Beetles or Wood Borers. Amer. Ent., Vol. III, pp. 237-239, 270-271.

No. General Index and Supplement to the Nine Reports on the Insects of Missouri. U. S. Dept. of Interior. U. S. Ent. Comm., Bull. No. 6. pp. 178.

1885. Fourth Report of the U. S. Entomological Commission, etc. (On the Cotton and Boll Worm.) U. S. Dept. Agr. pp. 399.

SCHWARZ, E. A.

1890. Food-Plants and Food-Habits of Some North American Coleoptera. Proc. Ent. Soc. Wash. Vol. I, pp. 231–233.

SCUDDER, S. H.

1889. Classified List of Food Plants of American Butterflies, drawn from Scudder's Butterflies of the Eastern United States. Psyche, Vol. V, pp. 274–278.

1901. Index to North American Orthoptera. Occasional Papers of the Bost. Soc. Nat. Hist., VI. pp. 436.

This is a complete alphabetical index to the literature of the species of North American Orthoptera—a unique and very useful work.

THOMAS, C., MIDDLETON, N., and MARTIN, J.

1881. Descriptive Catalogue of Larvæ. Tenth Rep. State Ent. Ill., pp. 60-140.

Description and keys to saw-fly and Lepidopterous larvæ.

TOWNSEND, C. H. T.

1893. A General Summary of the Known Larval Foodhabits of the Acalyptrate Muscidæ. Can. Ent., Vol. XXV, pp. 10-16.

WARD, H. B., WHIPPLE, G. C., and others.

Fresh Water Biology. (In press.) New York.

This work consists of chapters by numerous specialists on the various groups of fresh-water animals including insects, gives keys for the determination of specimens, short chapters on their general biological relations, and references to the literature.

VII. THE LAWS OF ENVIRONMENTAL CHANGE, OR THE "ORDERLY SE-QUENCE OF EXTERNAL NATURE"

THE DYNAMIC AND PROCESS RELATIONS OF THE ENVIRONMENT

"Of all the truths relating to phenomena, the most valuable to us are those which relate to the order of succession. On a knowledge of these is founded every reasonable anticipation of future facts, and whatever power we possess of influencing those facts to our advantage."—John Stuart Mill.

"To study life we must consider three things: first, the orderly sequence of external nature; second, the living organism and the changes which take place in it; and, third, the continuous adjustment between the two sets of phenomena which constitutes life." — W. K. Brooks.

"The truth, indeed, is, that in physical inquiries, the work of theory and observation must go hand in hand, and ought to be carried on at the same time, more especially if the matter is very complicated, for there the clue of theory is necessary to direct the observer. Though a man may begin to observe without any hypothesis, he cannot continue long without seeing some general conclusion arise; and to this nascent theory it is his business to attend, because, by seeking either to verify or to disprove it, he is led to new experiments, or new observations. He is led also to the very experiments and observations that are of the greatest importance, namely to those instantiae crucis, which are the criteria that naturally present themselves for the trial of

every hypothesis. He is conducted to the places where the transitions of nature are most perceptible, and where the absence of former, or the presence of new circumstances, excludes the action of imaginary causes. By this correction of his first opinion, a new approximation is made to the truth; and by the repetition of the same process, certainty is finally obtained. Thus theory and observation mutually assist one another; and the spirit of system, against which there are so many and such just complaints, appears, nevertheless, as the animating principle of inductive investigation. The business of sound philosophy is not to extinguish this spirit, but to restrain and direct its efforts."

- J. Playfair, "Illustrations of the Huttonian Theory of the Earth," Edinburgh, 1802, pp. 524-525.

THE facts and ideas with which the animal ecologist needs to become acquainted are so widely scattered that a large amount of selective reading is necessary. The ecologist must read, select, and become an organizing center of things ecological. All of the facts and conceptions which he needs are not even confined to zoölogical or biological literature. In seeking an understanding of any problem, conventional groupings of the sciences and their arbitrary boundaries must not bar one from fertile fields. Many of the conceptions of the physical sciences, due to their more advanced stage of development, anticipate the future development of biology. This is particularly true of their dynamic conceptions. For this reason we should not hesitate to utilize and deliberately strive to secure development along similar lines in animal ecology. Elsewhere I have stated (An Ecological Survey in Northern Michigan, 1906, pp. 11, 12) that: "It is thus very apparent

that as soon as ecological phenomena are investigated dynamically and expressed in terms of processes, this science will of necessity become more closely correlated with those allied sciences which have already availed themselves of such methods. . . . It seems a very simple matter to give assent to the idea of the law of change, yet in its practical application this simplicity often vanishes at once when it is seen that it involves the relation of cause and effect. ... As this method of thinking is not generally understood, it is occasionally applied in such a crude and general sense that its bearing cannot be grasped when applied to special or concrete problems. There can be no question as to the general validity of this method, but what is now needed is to know how these processes are combined and related to produce particular environmental conditions or situations. That these difficulties are not confined to the ecologist alone, but are obstacles which arise in any attempt at scientific interpretation, is worthy of special notice. We are thus able to see why certain naturalists, apparently not recognizing or understanding the developmental processes which scientific ideas undergo, nor being acquainted with the tendencies of interpretation, dynamically considered, now making such rapid headway in ecological botany, geography, physiography, geology, and psychology, are inclined to look upon such attempts in biology as merely a fad or personal peculiarity of the student, and not of any particular consequence. Such ideas confuse the incidental with the essential and suggest a complete failure to grasp the situation or to realize the fundamental importance of stating explanations in terms of processes. Furthermore, in several of the allied sciences, the methods of dynamical interpretation have already made considerable advance. Here, then, is a resource, at present largely unworked by many biologists, where a wealth of ideas and explanations lies strewn over the surface and only need to be picked up in order to be utilized by those acquainted with this method of interpretation. . . . If the signs of the times are now read correctly, the most striking advance in scientific methods of thinking during the present century will be in the direction of interpretation from the standpoint of processes — dynamically."

For these reasons I have begun the list of literature with certain references which deal with the dynamic relations of the environment. These publications are particularly valuable not only for this method of treatment, but also for their content. These papers clearly emphasize the "orderly sequence of external nature," a conception which must be grasped much more than superficially, if one is to interpret the development or evolution of environments. Although this is an essential part of our problem, as has been so well expressed by Brooks, yet this phase is probably one of the least understood by zoölogists. 'And as long as zoölogical students lack the proper training this condition will continue. To neglect this aspect in the training of an ecologist is like neglect of chemical training in a physiologist or of a physiological training in a psychologist. For one who is ignorant of the principles of "orderly sequence," or successions of changes occurring in the physical, vegetational, and animal environments, it is manifestly impossible to realize their development; and the application of such principles to the interpretation of practical problems is utterly beyond his grasp. We are thus able to see that although the phrase "orderly sequence of external nature" is fundamentally a simple conception, it is not grasped without effort, training, and careful investigation.

Obviously it is impossible to arrange the series of references with perfect satisfaction. The arrangement which will serve one purpose will not another, and for this reason it has been necessary to arrange the lists in more than one order. Certain general references, or some intended to facilitate the acquirement of the general point of view, are given first, and others are arranged alphabetically. For example, the papers listed on the processes of change in the physical and vegetational environment are approximately in an order in which they may profitably be studied to make the view as concrete as possible. It is primarily not the abstract idea of the principle of change, which is relatively easy to grasp, but to be able to apply it to any condition or location and to make it a guiding principle is very difficult. And judging from my own observation upon others and my own experience this method is very rarely mastered, if at all, unless it is actually worked out in

some concrete case, and later expanded to its logical consequences.

Only a few references are given on general physiology, metabolism, and allied subjects, but those given furnish a valuable index to further literature. Only the most arbitrary line can be drawn between papers dealing with habits, behavior, and individual ecology, and for this reason most of the references selected are arranged alphabetically.

Particular attention should be called to the fact that it is not to be assumed that the various authors strive to make the points to which attention is here called; they may or may not do so. My aim is to call attention to the *utility* of the publications from the *standpoint* advocated throughout the book.

From this point onward in this book the references form its main feature. For this reason it is important that one should not get an exaggerated idea of the value of the literature. It is perhaps true that a large part of the best ecological work has been done with little knowledge of other ecological writings. This was of course particularly true of the early workers, and the best work of to-day does not come from the largest library centers. A student looking over these lists, and finding that he has access to relatively few papers, may conclude that all effort is of no avail. The greatest need is not all or even a majority of the publications on the general field, but the relatively limited number which bear directly upon the problem at hand and enough of the general papers to aid him in a general orientation.

It may be of some comfort to the isolated student, with his small shelf of books, to realize that there are perhaps not a half-dozen libraries in America which contain all the references given in this book. The nearer one reaches the boundaries of our knowledge, the smaller the amount, and often the smaller the value of the literature, and the greater the value of a proper orientation, which comes only with a grasp of general principles.

(The laws of physical and vegetational changes and their influence upon animals. The dynamic or process relation of the environment.)

BANCROFT, W. D.

1911. A Universal Law. Science, N. S., Vol. XXX, pp. 159-179.

The law of adjustment or response to strain. A very important paper viewed from the dynamic and process standpoint.

HENDERSON, L. J.

1913. The Fitness of the Environment. An Enquiry into the Biological Significance of the Properties of Matter. pp. 317. New York. The Macmillan Company.

Valuable ecologically because of its exposition of the orderly sequence and regulatory character of physicochemical and physiological processes, and the application of chemical equilibria and the Phase Rule to metabolic changes. He says, "Now there can be no doubt that, when feasible, the ideal method—from the physico-chemical point of view—to describe a material system is in terms of the phase rule." p. 260.

CHAMBERLIN, T. C., and SALISBURY, R. D.

1904. Geology. Geologic Processes and their Results, Vol. I. pp. 654. New York.

To be considered from the standpoint of the agents and processes which change animal habitats and result in their "orderly sequence."

,VAN HISE, C. R.

1904. A Treatise on Metamorphism. U. S. Geol. Survey, Monog., Vol. XLVII, pp. 1-1286.

A formidable-looking volume on account of its size, but one which will abundantly repay a careful study of its method, aside from the value of the content, for problems related to animals of the soils, etc. Particular attention should be given to the formulation of dynamic principles, and the application of the process method.

Davis, W. M.

1909. Geographical Essays. pp. 777. New York.

Essays on the orderly sequence of changing land forms, or to the ecologist, the development of inland habitats, in so far as they are dependent upon the physiographic conditions.

WOODWORTH, J. B.

1894. The Relation between Baseleveling and Organic Evolution. Amer. Geol., Vol. XIV, pp. 209-235.

The influence of baseleveling factors in the development of the gross environment and upon evolution.

ADAMS, CHAS. C.

1901. Baseleveling and its Faunal Significance, with Illustrations from Southeastern United States. Amer. Nat., Vol. XXXV, pp. 839-852.

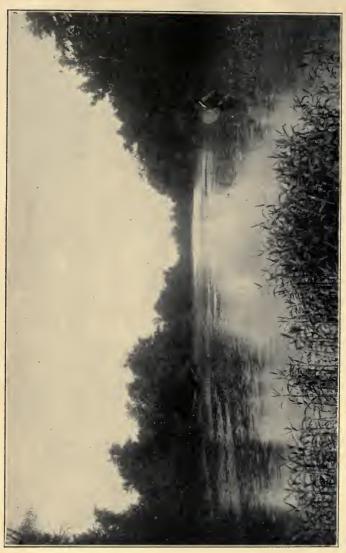
The influence of baseleveling upon the sequence of changes in fresh-water and land habitats. (See Figures 4 and 5.)



Fig. 4.—A small stream as an animal environment, with the preponderance of rapidly flowing water. Tumwater Canon, near Wenatchee, Washington. Photo. by W. B. McCallum.







topographic development, such as is shown in Fig. 4, is here replaced by long pools of relatively quietly flowing water, connected by narrow stretches of more rapidly flowing water. Wabash River, Bluffton, Indiana. Photo. by N. Miller and E. B. Williamson. Fig. 5.—A small river as an animal environment. The rapid water conditions of a stream in an early stage of

BRANDT, K.

1899. Ueber den Stoffwechsel im Meere. Wissen. Meeruntersuchungen, heraus. v. d. Komm. zur wissen. Unters, deutschen Meere in Kiel. N. F. Abth. Kiel, Bd. IV, pp. 213-230.

Life in the Ocean. Smithsonian Report for 1900, pp. 493-506.

> A translation of the preceding paper on the transformation of substance or "cycle of matter" in the sea. The extensive footnotes are omitted.

Heber den Stoffwechsel im Meere, 2 Abhand, Wiss, 1902. Meeresunt. heraus. v. d. Komm. zur wissen. Unters. deutschen Meere in Kiel, N. F. Bd. VI. Abth. Kiel, pp. 23-79.

On the Production and Conditions of Production in 1905. the Sea. Rapports et Procés-Verbaux, Inter. Council for the Exploration of the Sea, Vol. III, Appendix D. Copenhagen.

> Not seen by the writer. Johnstone states that it is a summary of the papers of 1899 and 1902.

JOHNSTONE, J.

1908. Metabolism in the Sea. pp. 206-298. In "Conditions of Life in the Sea." Cambridge, England.

BIRGE, E. A.

1907. The Respiration of an Inland Lake. Trans. Amer. Fisheries Soc., Vol. XXXVI, pp. 223-241.

The Thermocline and its Biological Significance. Trans. Amer. Micros. Soc., Vol. XXV, pp. 5-33. Two studies in the sequential changes in the lake habitat.

BIRGE, E. A., and JUDAY, C.

1911. The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and their Biological Significance. Wis. Geol. and Nat. Hist. Survey, Bull. No. 22. pp. 259.

PETERS, A. W.

1907. Chemical Studies on the Cell and its Medium. Part II, Some Chemico-Biological Relations in Liquid Culture Media. Amer. Jour. Physiol., Vol. XVIII, pp. 321-346.

A study of changes in media and their biotic succession.

COWLES, H. C.

1911. The Causes of Vegetative Cycles. Bot. Gaz., Vol. LI, pp. 161-183. Also Ann. Associa. Amer. Geogr., Vol. I, pp. 1-20. 1912.

> An important statement of the general principles and causes of vegetational changes. Includes a history of the subject.

1901. The Physiographic Ecology of Chicago and Vicinity; A Study of the Origin, Development, and Classification of Plant Societies. Bot. Gaz., Vol. XXXI, pp. 73-108, 145-182.

A study of changes in the vegetation from the process and genetic standpoint.

CLEMENTS, F. E.

The Development and Structure of Vegetation. Bot. Surv. Nebraska, VII. pp. 175. Lincoln.
 Deals with vegetative changes from the process standpoint.

 Research Methods in Ecology. pp. 334. Lincoln, Neb.

CRAMPTON, C. B.

1911. The Vegetation of Caithness Considered in Relation to the Geology. pp. 132. Comm. for the Survey and Study of British Vegetation.

1912. The Geological Relations of Stable and Migratory Plant Formations. Scottish Bot. Rev., Vol. I, pp. 1-61.

Good examples of the process standpoint as applied to the vegetation.

WARMING, E. (Trans. by P. Groom and I. B. Balfour.)

1909. Œcology of Plants. pp. 422. Oxford.

A treatise on the general principles of plant ecology, and an index to the literature.

ZON, RAPHAEL.

1906. Principles Involved in Determining Forest Types.
 Proc. Soc. Amer. Foresters, Vol. I, pp. 179-189.
 Discusses the sequence of change in the forest.

OSTENFELD, C. H.

1908. On the Ecology and Distribution of the Grass-Wrack (Zostera marina) in Danish Waters. Rep. Danish Biol. Sta. to Board of Agriculture, Vol. XVI, 1908. Trans. from the Fiskeri-Beretning for 1907, pp. 1-62.

An important paper showing the controlling relation of marine vegetation upon animal associations and particularly the fish of the coast. References to related zoölogical papers.

MOORE, J. E. S.

1903. The Tanganyika Problem. pp. 371. London.

On pp. 107-119 Moore describes the invasion and succession of vegetation upon alluvial flats, recently drained. A graphic account of forest invasion. Apparently a little known study.

ERNST, A. (Trans. by A. C. SEWARD.)

1908. The New Flora of the Volcanic Island of Krakatau. pp. 74. Cambridge.

A study of the invasion of vegetation upon a new land surface formed by volcanic activity. Such studies as this aid one in breaking away from the older static view of vegetation and in seeing its more vital aspect.

VAUGHAN, T. W.

7 The Geological Work of Mangroves in Southern Florida. Smithsonian Miscell. Coll. (Quart. Issue), Vol. LII, pp. 461-464.

Plants as agents in the formation of animal habitats.

WEISS, F. E.

1909. A Preliminary Account of the Submerged Vegetation of Lake Windermere as Affecting the Feeding Ground of Fish. Mem. and Pro. Manchester Lit. and Phil. Soc., Manchester Memoirs, 1908–1909, Vol. LIII, Mem. 11, pp. 1–9.

TRANSEAU, E. N.

1908. The Relation of Plant Societies to Evaporation. Bot. Gaz., Vol. XLV, pp. 217-231.

Shows vegetational control upon the relative humidity of the air.

FULLER, G. D.

1911. Evaporation and Plant Succession. Bot. Gaz., Vol. LII, pp. 193-208.

Further studies of the vegetational control of the relative evaporating power of the air.

SHELFORD, V. E.

1907. Preliminary Note on the Distribution of the Tiger Beetles (Cicindela) and its Relation to Plant Succession. Biol. Bull., Vol. XIV, pp. 9-14.

> The sequence of vegetational changes which determine the habitats of a predaceous insect.

1912. Ecological Succession. IV. Vegetation and the Control of Land Animal Communities. Biol. Bull., Vol. XXIII, pp. 59-99.

> An important paper correlating the development of the vegetation and the changing animal associations.

Cook, O. F.

Vegetation Affected by Agriculture in Central America. U. S. Dept. Agr., Bur. Plant Industry, Bull. No. 145. pp. 30.

> Vegetational change in the tropics as affected by man and its relation to plant succession.

FERNOW, B. E., and HARRINGTON, M. W., and others.

7 1893. Forest Influences. U. S. Dept. Agr., Forestry Div., Bull. No. 7. pp. 197.

Very valuable discussion of the atmospheric conditions in and about woodlands; temperature, evaporation, etc., in open and wooded areas. Not written from the process standpoint, but capable of such an interpretation. (See Figures 6 and 7.)

Adams, Chas. C.

1905. The Postglacial Dispersal of the North American Biota. Biol. Bull., Vol. IX, pp. 53-71.

Climatic sequences applied to inland habitats and the succession of their associations.

1909. Isle Royale as a Biotic Environment. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 1-56.

An attempt is made to treat the environment and biota from both the dynamic or process standpoint — so far as the present processes are concerned — and genetically with regard to the development of the present conditions.

RUTHVEN, A. G.

1906. An Ecological Survey in the Porcupine Mountains and Isle Royale, Michigan. Ann. Rep. Mich. Geol. Surv. for 1905, pp. 17-55.

The environment and biotic associations are treated from the dynamic and genetic standpoint.

VIII. THE LAWS OF ORDERLY SEQUENCE OF METABOLISM, GROWTH, DEVELOP-MENT, PHYSIOLOGICAL CONDITIONS, AND BEHAVIOR, OR "THE LIVING ORGANISM AND THE CHANGES WHICH TAKE PLACE IN IT"

THE DYNAMIC OR PROCESS RELATIONS OF THE ANIMAL

- 1. General Physiology and Development.
- 2. A Selection of Physiological and Ecological Papers.
- 3. Animal Behavior as a Process.
- 4. A List of Selected Reviews and Bibliographies.
- 5. A Selection of References on Life Histories and Behavior.

"Seeing, then, that in all cases we may consider the external phenomena as simply in relation, and the internal phenomena also as simply in relation; the broadest and most complete definition of Life will be — The continuous adjustment of internal relations to external relations."—HERBERT SPENCER.

"It is of the utmost importance, if we are to understand the behavior of organisms, that we think of them as dynamic — as processes, rather than as structures. The animal is something happening."—H. S. Jennings (1907).

Not only is the environment subject to an orderly sequence of changes, but this same law applies with equal thoroughness to the living animal itself. The animal is an agent which transforms, in "an orderly sequence," by its processes of metabolism, both energy and substance, resulting in growth, differentiation, multiplication, and behavior. These activities take place in an orderly manner and are dependent upon both energy and substance derived from the environment. For these reasons the processes or changes in metabolism, growth, development, and behavior, in so far as they are responses to the orderly sequence of environmental changes, are ecological problems. The changes in behavior during the life of the animal or the development of its behavior give one of the main clues to the physiological conditions which determine some of the most characteristic forms of responses, and finally as a result of all these activities and processes of adjustment to the conditions of life, a relatively mature and adjusted condition of the struggle for existence in animals and associations may be reached, the culmination of animal harmonies. For this reason studies in modifications of behavior are of fundamental ecological importance, because they consider behavior not only as ready-made, but also in the process of making. Such considerations as these make it desirable to include some of the most valuable and suggestive books and papers which deal with those general physiological processes influencing growth, development, multiplication, and behavior, and particularly those which aid one in realizing their order or successive changes, or "orderly sequence."

In studying the activities of the individual animal, the normal environment to which it is attuned

forms the natural unit or basis for study. All processes which modify or change such an optimum will stimulate the animal, cause responses and adjustments. There are many degrees or stages in the development of these optima which change with the functional rhythms and with the development of the animal. There are those conditions which influence the activity of certain functions or organs; those which influence the general vital processes in general, the vital optimum; those which appear to condition the best development of certain families, genera, etc.; and finally those of animal associations. Of course these grade imperceptibly into one another, and a single animal may in its development, traverse all of these stages in the development of its associational optimum. Optima thus have histories, and their development and laws of transformation are of the most fundamental ecological importance (Adams, 1904, 1909; Blackman, 1905, 1906; Shelford, 1911, 1912).

In the selection of these papers I have been guided by several considerations. Studies of common animals are given preference, also those papers which by their method of treatment and point of view are especially suggestive and may act as models for further study, and particularly those papers which treat of the activities from the standpoint of their changes, cycles, modifiability, and development. It is to such papers that we must look for suggestions regarding the methods or processes of adjustment between the animal and the environment. All of these papers are not equally ecological, but all will be of much utility in ecological work.

(General works are listed first, followed by special papers arranged alphabetically.)

1. General Physiology and Development

VERWORN, M.

1899. General Physiology. pp. 615. New York.

A very good general summary, but somewhat out of

A very good general summary, but somewhat out of date. There is a German edition of 1909 (fifth).

ROSENTHAL, J.

1901. Lehrbuch der Allgemeinen Physiologie. pp. 616. Leipzig.

FÜRTH, O. von.

1903. Vergleichende chemische Physiologie der niederen Tiere, pp. 670. Jena.

An excellent general work. Indispensable. Full references.

PÜTTER, A.

1911. Vergleichende Physiologie. pp. 721. Jena.

WINTERSTEIN, H. (Editor).

1910. Handbuch der vergleichenden Physiologie. (To be completed in four volumes.) Jena.

HAMMARSTEN, O. (Trans. by J. A. MANDEL.)

1911. A Text-Book of Physiological Chemistry. Sixth Edition. pp. 964. New York.

DAVENPORT, C. B.

1908. Experimental Morphology. pp. 509. New York.

Excellent summaries and full references to the influence of various stimuli upon growth and upon protoplasm.

LOEB, J.

1906. The Dynamics of Living Matter. pp. 233. New York.

PRZIBRAM, H.

Experimental-Zoologie. 3. Phylogenese. pp. 315.
 Leipzig and Vienna.

JENNINGS, H. S.

1906. Behavior of the Lower Organisms. pp. 366. New York.

The general chapters are particularly helpful.

MORGAN, T. H.

1907. Experimental Zoölogy. pp. 454. New York. Summaries of a variety of experimental studies.

SEMPER, K.

1881. Animal Life as Affected by the Natural Conditions of Existence. pp. 472. New York.

"'The Physiology of Organisms,' in contradistinction to the Physiology of Organs, . . . [is] that branch of animal biology which regards the species of animals as actualities and investigates the reciprocal relations which adjust the balance between the existence of any species and the natural, external conditions of its existence, in the widest sense of the term."

p. 33.

JENSEN, P.

1907. Organische Zweckmässigkeit, Entwicklung und Vererbung vom Standpunkt der Physiologie. Jena. pp. 251.

VERNON, H. M.

1903. Variation in Animals and Plants. pp. 415. London.

VARIGNY, H. DE.

1892. Experimental Evolution. pp. 271. New York.

BACHMETJEW, P.

1901–1907. Experimentelle entomologische Studien vom physikalisch-chemischen Standpunkt aus. Bd. I. Temperaturverhältnisse bei Insekten. pp. 160. Leipzig. 1901. Bd. II. Einfluss der Ausseren Faktoren auf Insekten. pp. 944. Sophia. 1907.

An extremely valuable index to environmental influences upon insects. Numerous summaries.

HERRICK, C. L.

1906. Applications of Dynamic Theory to Physiological Problems. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 362–375.

RICHARDS, H. M.

1910. On the Nature of Response to Chemical Stimulation. Science, N. S., Vol. XXXI, pp. 52-62.

SCHÄFER, E. A.

1912. The Nature, Origin and Maintenance of Life. Science, N. S., Vol. XXXVI, pp. 289-312.

BASKERVILLE, C.

1905. Life and Chemistry. Science, N. S., Vol. XXI, pp. 641-648.

MORGAN, T. H.

1910. Chance or Purpose in the Origin and Evolution of Adaptation. Science, N. S., Vol. XXXI, pp. 201– 210.

MATHEWS, A. P.

1905. A Theory of the Nature of Protoplasmic Respiration and Growth. Biol. Bull., Vol. VIII, pp. 331-346.

JENNINGS, H. S.

1912. Age, Death and Conjugation in the Light of Work on Lower Organisms. Pop. Sci. Mo., Vol. LXXX, pp. 563-577.

Death is due to differentiation and not to a "running down" of the organism.

LILLIE, F. R.

1909. The Theory of Individual Development. Pop. Sci. Mo., Vol. LXXV, pp. 239-252.

HOLMES, S. J.

1904. The Problem of Form Regulation. Archiv für Ent-

wickelungsmechanik der Organismen (Roux), Bd. XVII, pp. 265-305.

1907. Regeneration as Functional Adjustment. Jour. Exp. Zoöl., Vol. IV, pp. 419-430.

WILSON, E. B.

1905. The Problem of Development. Science, N. S., Vol. XXI, pp. 281-294.

SHERRINGTON, C. S.

1906. The Integrative Action of the Nervous System. pp.411. New York.

The activity of the nervous system is viewed as a regulatory process.

The similar responses to diverse stimuli or the similar results produced by diverse causes are the conditions which make an analysis and the isolation of causes necessary. With departures from the normal and optimum into zones of stimulation and of unfavorable conditions many similar effects or results are produced. The similar results of extremes of high and low temperature as shown in Fischer's experiments on Lepidoptera, and the effects of high temperatures, aridity, and the lack of oxygen may be cited as examples. Such effects have an important bearing upon the subject of physical and chemical limiting factors which influence individuals, aggregations, and associations.

BLACKMAN, F. F.

1905. Optima and Limiting Factors. Ann. of Bot., Vol. XIX, pp. 281-295.

"When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the 'slowest' factor." p. 289. 1908. The Manifestations of the Principles of Chemical Mechanics in the Living Plant. British Assoc. Adv. Sci., 1908, pp. 1-18.

Adams, Chas. C.

1904. On the Analogy Between the Departure from Optimum Vital Conditions and Departure from Geographic Life Centers. Science, N. S., Vol. XIX, pp. 210– 211.

GREELEY, A. W.

1901. On the Analogy Between the Effects of Loss of Water and Lowering of Temperature. Amer. Jour. Physiol., Vol. VI, pp. 122-128.

ZOETHOUT, W. D.

1899. On Some Analogies Between the Physiological Effects of High Temperature, Lack of Oxygen, and Certain Poisons. Amer. Jour. Physiol., Vol. II, pp. 220-242.

LYON, E. P.

1902. Effects of Potassium Cyanide and of Lack of Oxygen upon the Fertilized Eggs and the Embryos of the Sea-Urchin (*Arbacia punctulata*). Amer. Jour. Physiol., Vol. VII, pp. 56-75.

PACKARD, W. H.

1905. On Resistance to Lack of Oxygen and on a Method of Increasing this Resistance. Amer. Jour. Physiol., Vol. XV, pp. 30-41.

1907. The Effect of Carbohydrates on Resistance to Lack of Oxygen. Amer. Jour. Physiol., Vol. XVIII, pp. 164-180.

FISCHER, E.

1903. Lepidopterologische Experimental-Forschungen. III. Allgem. Zeit. für Entomologie, Bd. VIII, pp. 221–228.

> These experiments illustrate in a very striking manner how abnormally high and low temperatures produce the same kind of effect or response.

2. A Selection of Physiological and Ecological Papers
(Alphabetically arranged)

CLESSIN, S.

1897. Über den Einfluss der Umgebung auf die Gehäuse der Schnecken. Württemberg naturw. Jahreshefte 53, pp. 68–86.

COLTON, H. S.

1908. Some Effects of Environment on the Growth of Lymnaea columella Say. Proc. Acad. Nat. Sci. Phila., 1908, pp. 410-448.

KELLER, C.

1887. Humusbildung und Bodenkultur unter dem Einfluss tierischer Th\u00e4tigkeit.
Not seen.

KNAUTHE, K.

1898. Zur Kenntnis des Stoffwechsels der Fische. Archiv f. d. gesammte Physiol. (Pflüger), Bd. LXXIII, pp. 490-500.

LANG, A.

1888. Über den Einfluss der festsitzenden Lebensweise auf die Thiere und über den Ursprung der ungeschlichtlichen Fortpflanzung durch Theilung und Knospung. pp. 166. Jena.

LOCARD, A.

1892. L'Influence des Milieux sur le Développement des Mollusques. pp. 140. Lyon.

MARSHALL, F. H.

1910. The Physiology of Reproduction. pp. 706. London.

MILLER, N.

1909. The American Toad (Bufo lentiginosus americanus Le Conte). Amer. Nat., Vol. XLIII, pp. 641-668, 730-745.

A study of the natural history of a single species.

RIDDLE, O.

1909. The Rate of Digestion in Cold-Blooded Vertebrates,

— The Influence of Season and Temperature. Amer. Jour. Physiol., Vol. XXIV, pp. 447–458.

RUSSELL, E. S.

1908. Environmental Studies on the Limpet. Proc. Zoöl. Soc., London, 1907, pp. 856-870.

SCHIEMENZ, P.

1911. Vergleichung der Fruchtbarkeit von Seen und Flussen.
 Aus deutscher Fischerei. pp. 75-82. Neudamm.
 A comparison of the relative productivity of fish in standing and running water environments.

SHELFORD, V. E.

1911. Physiological Animal Geography. Jour. Morph., Vol XXII, pp. 551-618.

An important paper. Explains the habitats and distribution of animals as due to physiological responses and characters. The dynamic and genetic standpoint of the present writer (p. 555) is erroneously contrasted with a physiological process. The dynamic includes all processes, the physiologic process is a species of this genus. The genetic is the application of processes to explain origins. The responsive and functional processes are dynamic in character.

1912. Ecological Succession. V. Aspects of Physiological Classification. Biol. Bull., Vol. XXIII, pp. 331-370. Further studies along the lines of the preceding paper.

VIRE, A.

1896. Modifications Produced in the Organs of Sense and of Nutrition in Certain Arthropods by Confinement in Caves. Ann. Mag. Nat. Hist. (6), Vol. XVII, pp. 407–408.

Vosseler, J.

1902. Über Anpassung und chemische Vertheidigungs mittel bei nordafrikanischen Orthopteren. Verh. Deutsch. Zool. Gesell. 1902, pp. 108–120. 1902-1903. Beiträge zur Faunistik und Biologie der Orthopteren Algeriens und Tunesiens. Zool. Jahrb. Abteilung f. Syst. Geog. u. Biol. der Tiere, Bd. XVI, pp. 337-404; Bd. XVII, pp. 1-98.

3. Animal Behavior as a Process

"The actual method of work is to first watch the organism under its natural environment, until one finds out all things it does. Then the environment is changed a little, to see what difference this makes in the behavior. We thus try all sorts of different ways of getting the animal to change its behavior, — including the application of definite chemical and physical reagents of most varied character. . . . We thus try to find the organism's system of behavior and the things that influence it, — becoming acquainted with the creature as we might get acquainted with a person with whom we are thrown much in contact."

-H. S. JENNINGS (1910).

"My object being the study of the correlative instincts of the young and adult in relation to all that could be learned about them in a natural environment, I have followed my usual custom of going out to the birds, instead of taking them into the laboratory. The facts which the laboratory can be made to yield are invaluable, but they belong to a different class from those for which we are now mainly in search, behavior under the usual or normal conditions."—F. H. HERRICK (1910).

"As will be seen, these studies include both field and laboratory work, especially of the American species, and I have made the field work emphatic wherever at all practicable. I have elsewhere (1909, p. 157) [Jour. Exp. Zoöl., Vol. VII] emphasized the crying need for larger attention to this phase of experimental work, believing that in many cases it is all but impossible to secure trustworthy results as to behavior of animals where the work has been done under such unusual, unnatural and artificial conditions as most laboratory provisions afford. What right

has one to assume that the actions of an animal taken rudely from its natural habitat and as rudely imprisoned in some improvised cage are in any scientific sense an expression of its normal behavior, either physical or psychical? Is it within the range of the calculus of probability that conclusions drawn from observations made upon an animal in the shallow confines of a finger-bowl, but whose habitat has been the open sea, are wholly trustworthy? It is no part of my purpose to discredit the laboratory or laboratory appliances as related to such investigations. They are indispensable. But at the same time let it be recognized that they are at best but artificial makeshifts whose values, unless checked up by constant appeal to nature, must be taken at something of discount. . . . It seems to the writer that until one has been able to place his specimens under conditions approximating the natural, or has at least brought them to a state of semi-domestication, where in food-taking, evidence of health, etc., they are at ease, he has small right to dogmatize as to conclusions, or presume to make such conclusions the basis of so-called laws of behavior. Not a little of recent investigation along the lines of behavior has been vitiated at just this point, and must be repeated to be made trustworthy. The amazing mass of contradictory results which has loaded the literature of recent years is attributable to some extent to this misfortune."—C. W. HARGITT (1912).

"We are apt to contrast the extremes of instinct and intelligence, to emphasize the blindness and inflexibility of the one and the consciousness and freedom of the other. It is like contrasting the extremes of light and dark and forgetting all the transitional degrees of twilight. . . . Instinct is blind; so is the highest human wisdom blind. The distinction is one of degree. There is no absolute blindness on the one side, and no absolute wisdom on the other."—C. O. Whitman (1899).

The precedence here given to changes in behavior is in harmony with the emphasis which is put upon

processes and genetic phases or sequences throughout this book. As Holmes (1905, p. 108) has well pointed out, behavior consists of relatively fixed and relatively changeable responses, with intergradations. There are thus two avenues of approach which he sums up as follows (p. 112): "In the trial and error method the random character of the movement impresses us most; in the tropisms, the element of direct determination by the environment. Both of these factors run through the behavior of all animals, but they are mingled in various proportions in different forms. In the lives of most, if not all animals both are essential elements in the adjustment of the organism to its conditions of existence." And in regard to those responses which do not change in form with experience, he says (p. 106): "The element of spontaneous undirected activity is one of vast if not essential importance in the life of nearly all animals. The simpler animals profit by their varied experience, although they may not learn, and thus secure some of the advantages which it is generally considered the special function of intelligence to confer." Thus to the ecologist studying the sequences of changes in the environment, and changes in the organism, it is but natural and consistent for him to apply the same methods to behavior, in order to facilitate their mutual relations and aid in their interpretation. In a study of the environment we also have the relatively stable elements and the relatively rapidly changing ones, and any adequate understanding of animals must correlate these four variables: two relatively

changing, one in the organism and one in the environment; and two others relatively stable, one in the organism and the other in the environment.

JENNINGS, H. S.

1905. The Method of Regulation in Behavior and in Other Fields. Jour. Exp. Zoöl., Vol. II, pp. 473-494.

HOLMES, S. J.

1905. The Selection of Random Movements as a Factor in Phototaxis. Jour. Comp. Neurol. and Psychol., Vol. XV, pp. 98-112.

JENNINGS, H. S.

1905. Modifiability in Behavior. I. Behavior of Sea Anemones. Jour. Exp. Zoöl., Vol. II, pp. 447-472.

1906. Modifiability in Behavior, II. Factors Determining Direction and Character of Movement in the Earthworm. Jour. Exp. Zoöl., Vol. III, pp. 435-455.

1906. Behavior of the Lower Organisms. pp. 366. New York.

Behavior of the Starfish (Asterias Forreri De Loriol).
 Univ. Calif. Pub. Zoöl., Vol. IV, pp. 53-185.

WALTER, H. E.

1907. The Reactions of Planarians to Light. Jour. Exp. Zoöl., Vol. V, pp. 35-162.

YERKES, R. M.

1901. The Formation of Habits in the Turtle. Pop. Sci. Mo., Vol. LVIII, pp. 519-525.

PEARL, R.

1904. On the Behavior and Reactions of Limulus in Early
Stages of its Development. Jour. Comp. Neurol.
and Psychol., Vol. XIV, pp. 138-164.

HADLEY, P. B.

1908. The Behavior of the Larval and Adolescent Stages of the American Lobster (Homarus Americanus). Jour. Comp. Neurol. and Psychol., Vol. XVIII, pp. 199-301. MAYER, A. G., and Soule, C. G.

1906. Some Reactions of Caterpillars and Moths. Jour. Exp. Zoöl., Vol. III, pp. 415-433.

CRAIG, W.

1908. The Voices of Pigeons Regarded as a Means of Social Control. Amer. Jour. Sociol., Vol. XIV, pp. 86–100.

HERRICK, F. H.

1912. Organization of the Gull Community. Proc. Seventh Inter. Zoöl. Cong., Boston, 1907, pp. 156-158.

YERKES, A. W.

1906. Modifiability of Behavior in Hydroides Dianthus V. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 441-449.

YERKES, R. M., and HUGGINS, G. E.

1903. Habit Formation in the Crawfish, Cambarus affinis. Psychol. Rev.; Series of Monog. Suppl., Vol. IV, No. I; Harvard Psychol. Studies, Vol. I, pp. 565-577.

YERKES, R. M.

1905. Animal Psychology and the Criteria of the Psychic. Jour. Phil., Psychol., and Sci. Methods, Vol. II, pp. 141-149.

1905. Concerning the Genetic Relations of Types of Action. Jour. Comp. Neurol. and Psychol., Vol. XV, pp. 132-137.

ALLEE, W. C.

1912. An Experimental Analysis of the Relation between Physiological States and Rheotaxis in Isopoda.

Jour. Exp. Zoöl., Vol. XIII, pp. 269-344.

A study of the responses of pond and stream Isopods to natural and experimental conditions.

WASHBURN, M. F.

1908. The Animal Mind. pp. 333. New York.

For modifications of behavior by experience see pp.

205-269. Also many references on behavior.

4. A List of Selected Reviews and Bibliographies

1911. [Reviews of papers on animal behavior for 1910.]

Jour. Animal Behavior, Vol. I, pp. 393-455, 465-470.

Reviews by Holmes, Turner, Wheeler, Watson, and Bohn.

JENNINGS, H. S.

1909. The Work of J. von Uexkuell on the Physiology of Movements and Behavior. Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 313-336.

CONGDON, E. D.

1908. Recent Studies upon the Locomotor Responses of Animals to White Light. Jour. Comp. Neurol. and Psychol., Vol. XVIII, pp. 309–328.

MAST, S. O.

1910. Literature of the Past Year on the Behavior of Lower Organisms. Psychol. Bull., Vol. VII, pp. 267-280.

Recent Literature on the Behavior of the Lower Invertebrates. Psychol. Bull., Vol. VIII, pp. 263-277.

YERKES, R. M.

1906. George Bohn's Studies in Animal Behavior. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 231-238.

WASHBURN, M. F.

1908. French Work in Comparative Psychology for the Past Two Years. Jour. Comp. Neurol. and Psychol., Vol. XVIII, pp. 511-520.

WASHBURN, M. F. (Editor).

1912. Comparative Psychology Number. Psychol. Bull.,
 Vol. IX, No. 8, pp. 281-313.
 Reviews by Pearse, Turner, and Washburn.

Coues, E.

71877. Monograph of North American Rodentia. Rep. U. S. Geol. Surv. Terr. (Hayden), Vol. XI.

Contains on pp. 255-264 and 951-1081 an extensive bibliography of North American mammals, and includes much on their habits.

5. A Selection of References on Life Histories and Behavior (Alphabetically arranged)

ANDREWS, E. A.

1906. Egg-laying of Crayfish. Amer. Nat., Vol. XL, pp. 343-356.

1904. Breeding Habits of Crayfish. Amer. Nat., Vol. XXXVIII, pp. 165-206.

BAKER, F. C.

1911. Ecology of Lymnæas. pp. 19-51. Lymnæidæ of North and Middle America Recent and Fossil. Special Pub. No. 3, Chicago Acad. Sciences.

BANTA, A. M.

1910. A Comparison of the Reactions of a Species of Surface Isopod with those of a Subterranean Species. Jour. Exp. Zoöl., Vol. VIII, Part I, Experiments with Light, pp. 243-310; Part II, pp. 439-488.

BELDING, D. L., and LANE, F. C.

1909. The Shellfisheries of Massachusetts: their Present Condition and Extent. Report upon the Mollusk Fisheries of Massachusetts, pp. 16-233. Boston.

Contains some excellent photographs of the habitat.

A Report upon the Scallop Fishery of Massachusetts, including the Habits, Life History of Pecten irradians, its Rate of Growth, and Other Facts of Economic Value. pp. 150. Boston.

The Life History and Growth of the Quahaug (Venus 1911. mercenaria). Rep. Mass. Comm. Fisheries and Game for 1910, pp. 18-128. Boston.

> These papers are examples of applied ecology, and contain much on the life histories and habits of these mollusks.

BENDIRE, C.

1892. Life Histories of North American Birds with Special Reference to their Breeding Habits and Eggs, with Twelve Lithographic Plates. Smithsonian Inst., Special Bull. No. 1. pp. 414.

1895. Life Histories of North American Birds, from the Parrots to the Grackles, with Special Reference to their Breeding Habits and Eggs. Smithsonian Inst., Special Bull. pp. 508.

BLACKWALL, J.

1873. Researches in Zoölogy. London. Not seen by writer.

BÖVING, A. G.

1910. Natural History of the Larvæ of Donaciinæ. Inter. Revue der gesamten Hydrobiol. u. Hydrog., Bd. III, Biol. Suppl., Heft I, pp. 1-108.

BUTTEL-REEPEN, H. von. (Trans. by M. H. GEISLER.)

1907. Are Bees Reflex Machines? Experimental Contribution to the Natural History of the Honey-bee. pp. 48. Medina, Ohio.

CALKINS, M. W.

1905. The Limits of Genetic and of Comparative Psychology.

Jour. of Psychol., Vol. I, pp. 261–285; Inter. Cong. of Arts and Sciences, St. Louis, Vol. V, pp. 712–734.

CARPENTER, F. W.

1908. Some Reactions of Drosophila, with Special Reference to Convulsive Reflexes. Jour. Comp. Neurol. and Psych., Vol. XVIII, pp. 483-491.

1910. Feeding Reactions of the Rose Coral (Isophyllia). Proc. Amer. Acad. Arts and Sciences, Vol. XLVI, pp. 149-162.

CASTEEL, D. B.

1911. The Discriminative Ability of the Painted Turtle. Jour. Animal Behavior, Vol. I, pp. 1-28.

CLARKE, W. E.

1912. Studies in Bird Migration. Vol. I, pp. 323; Vol. II, pp. 346. London.

Bird migration may be studied as a response of the

animals to the conditions of their life, and the above work is a good example of the best kind of work being done along this line.

COLE, L. J.

1907. An Experimental Study of the Image-Forming Powers of Various Types of Eyes. Proc. Amer. Acad. Arts and Sci., Vol XLII, pp. 335-417.

A study of worms, insects, sow bug, snail, slug, and frogs.

1913. Direction of Locomotion of the Starfish (Asterias Forbesi). Jour. Exp. Zoöl., Vol. XIV, pp. 1-32.

COLE, L. W.

1907. Concerning the Intelligence of Raccoons. Jour. Comp. Neurol. and Psychol., Vol. XVII, pp. 211-261.

 Observations on the Senses and Instincts of the Raccoon. Jour. Animal Behavior, Vol. II, pp. 299-309.

COLE, L. W., and LONG, F. M.

1909. Visual Discrimination in Raccoons. Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 657-683.

COLTON, H. S.

1908. How Fulgur and Sycotypus Eat Oysters, Mussels and Clams.' Proc. Acad. Nat. Sci. Phila., 1908, pp. 3-10.

COKER, R. E.

1906. The Natural History and Cultivation of the Diamond-Back Terrapin with Notes on other Forms of Turtles. Bull. No. 14, N. Carolina Geol. Survey, pp. 1-67.

CRAIG, W.

1909. The Expressions of Emotion in the Pigeons. I. The Blond Ring-Dove (*Turtor risorius*). Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 30-80.

DAWSON, J.

The Biology of Physa. Behavior Monographs, Vol. I, No. 4, pp. 1-120.
 Behavior is related to the natural environment.

DAVIS, H. B.

1907. The Raccoon: A Study in Animal Intelligence. Amer. Jour. Psychol., Vol. XVIII, pp. 447-489.

DEAN, B.

7 The Physical and Biological Characteristics of the Natural Oyster Grounds of South Carolina. Bull. U. S. Fish Comm. for 1890, Vol. X, pp. 335-361. Contains good illustrations of the oyster habitat.

DIMON, A. C.

1905. The Mud Snail: Nassa obsoleta. Cold Spring Harbor, Monogr. V. pp. 48.
 A behavior study of a marine snail.

EMBODY, G. C.

1912. A Preliminary Study of the Distribution, Food, and Reproductive Capacity of Some Fresh-water Amphipods. Inter. Revue. der gesamten Hydrobiol. u. Hydrog., Biol. Suppl. III. Serie, Heft 2, pp. 1-33.

ENTEMAN, M. M.

1902. Some Observations on the Behavior of Social Wasps. Pop. Sci. Mo., Vol. XLI, pp. 339-351.

FABRE, J. H. (Translated.)

1901. Insect Life. Souvenirs of a Naturalist. pp. 320.

FABRE, J. H. (Trans. by MIALL, B.)

1912. Social Life in the Insect World. pp. 327. London.

FLORENTIN, R.

1899. Études sur la Faune des Mares Salées de Lorraine. Ann. des Sci. Nat. Zoöl. (8° S.), Tome X, pp. 209-350.

Forel, A. (Trans. by Wheeler, W. M.)

1904. Ants and Some Other Insects. Religion of Sci. Library No. 56. pp. 49. Chicago.

Forel, A. (Trans. by Yearsley, M.)

1908. The Senses of Insects. pp. 324. London.

GILL, T.

1909. Contributions to the Life Histories of Fishes. Vol. I, 1904–1907. Smithsonian Institution, No. 1858.

A collection of reprints on the natural history of fishes, including much on their habits.

GRAVE, C.

1904. Investigations for the Promotion of the Oyster Industry of North Carolina. Rep. U. S. Fish Comm. for 1903, pp. 247-341.

On pp. 261-264 the growth or development of an oyster reef is described. This illustrates ecological succession on a reef. The food and the influence of storms are described.

GROOS, K. (Trans. by BALDWIN, E. L.)

1898. The Play of Animals. pp. 341. New York.

GURLEY, R. R.

 The Habits of Fishes. Amer. Jour. Psychol., Vol. XIII, pp. 408-425.

An important and apparently little known paper which explains the spawning habits of fish and their distribution in terms of their physiological responses. Compare with Shelford's Physiological Animal Geography. 1911.

HAHN, W.

1908. Some Habits and Sensory Adaptations of Caveinhabiting Bats. Biol. Bull., Vol. XV, pp. 135-193.

HARGITT, C. W.

1906. Experiments on the Behavior of Tubicolous Annelids. Jour. Exp. Zoöl., Vol. III, pp. 295-320.

1909. Further Observations on the Behavior of Tubicolous Annelids. Jour. Exp. Zoöl., Vol. VII, pp. 157-187.

1912. Observations on the Behavior of Tubicolous Annelids, III. Biol. Bull., Vol. XXII, pp. 67-94.

1912. Behavior and Color Changes of Tree Frogs. Jour. Animal Behavior, Vol. II, pp. 51-78.

HARRIS, J. A.

1903. An Ecological Catalogue of the Crayfishes belonging to the Genus *Cambarus*. Kan. Univ. Sci. Bull., Vol. II, pp. 51–187.

Habits and distribution of crawfish. Very useful references to the stream environment and to crawfish

HARTMAN, C.

1905. Observations on the Habits of Some Solitary Wasps of Texas. Univ. of Texas Bull. No. 65, Sci. Ser. No. 6, pp. 1-72.

HERRICK, C. J.

7¹⁹⁰³. The Organ and Sense of Taste in Fishes. Bull. U. S. Fish Comm. for 1902, Vol. XXII, pp. 237-272.

HERRICK, F. H.

1910. Instinct and Intelligence in Birds. Pop. Sci. Mo., Vol. LXXVI, pp. 532-556; Vol. LXXVII, pp. 82-97, 122-141.

1910. Life and Behavior of the Cuckoo. Jour. Exp. Zoöl., Vol. IX, pp. 169-233.

Illustrates the orderly sequence of forms of behavior.

Natural History of the American Lobster. Bull.
 U. S. Bur. Fisheries, Vol. XXIX, pp. 149-408.
 Doc. No. 747.

HODGE, C. F.

1894. The Methods of Homing Pigeons. Pop. Sci. Mo., Vol. XIV, pp. 758-775.

HOLMES, S. J.

1901. Observations on the Habits and Natural History of Amphithoe longimana Smith. Biol. Bull., Vol. II, pp. 165–193.

1906. Death-Feigning in Ranatra. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 200-216.

1908. The Instinct of Feigning Death. Pop. Sci. Mo., Vol. LXXII, pp. 179–185. 1911. The Evolution of Animal Intelligence. pp. 296.
New York.

JENNINGS, H. S.

1910. Diverse Ideals and Divergent Conclusions in the Study of Behavior in Lower Organisms. Amer. Jour. Psychol., Vol. XXI, pp. 349-370.

Valuable for its discussion of points of view in the study of behavior.

Kellogg, J. L.

7 Observations on the Life-History of the Common Clam, Mya Arenaria. Bull. U. S. Fish and Fisheries Comm. for 1899, Vol. XIX, pp. 193-202.

1903. Feeding Habits and Growth of Venus Mercenaria.
Bull. 71, N. Y. State Museum. pp. 27. Albany.

7 Conditions Governing Existence and Growth of the Soft Clam (Mya Arenaria). Rep. U. S. Comm. Fish and Fisheries for 1903, pp. 195-224.

A suggestive paper.

1905. Notes on Marine Food Mollusks of Louisiana. Bull. No. 3, Gulf Biologic Station. pp. 43. Baton Rouge.

> All of these papers by Kellogg are careful studies of the relation of animals to their environment. They also show the intimate relation of ecology to economic problems. Biological surveys intended for economic results should be ecological in their method.

1910. Shell-Fish Industries. pp. 361. New York, Henry Holt and Co.

A popular summary of the marine shell-fish industries of the American coast, from the standpoint of their biology, culture, and utilization. The oyster, hard and soft clams, and scallops are considered. The following subjects deserve mention: ciliary action, feeding reflexes, function of mucus, and food.

LEFEVRE, G., and CURTIS, W. C.

1912. Studies on the Reproduction and Artificial Propaga-

tion of Fresh-water Mussels. U. S. Bur. Fisheries for 1910, Bull. Vol. XXX, pp. 105-201.

Lyon, E. P.

1904. On Rheotropism. I. Rheotropism in Fishes. Amer. Jour. Physiol., Vol. XII, pp. 149-161.

MAST, S. O.

 Light and the Behavior of Organisms. pp. 410. New York.

An elaborate treatise on reactions to light.

MEAD, A. D.

1900. The Natural History of the Star-fish. U. S. Fish Comm. Bull. for 1899, Vol. XIX, pp. 203-224.

MICHAEL, E.

1911. Classification and Vertical Distribution of the Chætognatha of the San Diego Region. Univ. of Calif. Pub. Zoöl., Vol. VIII, pp. 21-186.

The distribution is studied as a response to the conditions of life, and the optima are determined.

MILLS, W.

1898. The Nature and Development of Animal Intelligence. pp. 307. New York.

Valuable account of the habits of squirrels. Observations on hibernation, and on the psychic development of the young of some of the domestic animals.

MONTGOMERY, T. H.

1903. Studies on the Habits of Spiders, particularly those of the Mating Period. Proc. Acad. Nat. Sci. Phila., 1903, pp. 59-149.

Contains a valuable bibliography.

1908. Further Studies on the Activities of Araneads. Amer. Nat., Vol. XLII, pp. 697-709.

1910. Further Studies on the Activities of Araneads, II. Proc. Acad. Nat. Sci. Phila., 1909, pp. 548-569.

1910. The Significance of the Courtship and Secondary Sexual Characters of Araneads. Amer. Nat., Vol. XLIV, pp. 151-177.

NEWMAN, H. H.

1906. The Habits of Certain Tortoises. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 126-152.

NEWMAN, H. H., and PATTERSON, J. T.

1909. Field Studies of the Behavior of the Lizard, Sceloporus Spinosus Floridanus. Bull. Univ. of Texas, No. 137, pp. 1-24.

ORTMANN, A. E.

1905. The Crawfishes of the State of Pennsylvania. Mem. Carnegie Mus., Vol. II, pp. 343-523.

Habits and habitats of crawfish.

PARKER, G. H.

1903. The Phototropism of the Mourning-cloak Butterfly, Vanessa Antiopa Linn. Mark Anniversary Volume, pp. 453-469. New York.

1903. The Sense of Hearing in Fishes. Amer. Nat., Vol. XXXVII, pp. 185-204.

1905. The Functions of the Lateral-Line Organs of Fishes. U. S. Bur. Fisheries, Bull. Vol. XXIV, pp. 185-207.

1908. The Sensory Reactions of Amphioxus. Proc. Amer. Acad. Arts and Sciences, Vol. XLIII, pp. 415-455.

1910. The Reactions of Sponges, with a Consideration of the Origin of the Nervous System. Jour. Exp. Zoöl., Vol. VIII, pp. 1-41.

PEARL, R.

1903. The Movements and Reactions of Fresh Water Planarians. Quart. Jour. Micros. Sci., Vol. XLVI, pp. 509-714.

A good example of a very detailed study of behavior of a lower animal.

PEARSE, A. S.

1910. The Reactions of Amphibians to Light. Proc. Amer. Acad. Arts and Sciences, Vol. XLV, pp. 161–208.

PECKHAM, G. W. and E. G.

1898. On the Instincts and Habits of the Solitary Wasps. Bull. No. 2, Wis. Geol. and Nat. Hist. Surv. pp. 245. 1905. Wasps, Social and Solitary. pp. 311. Boston and New York.

A revised and enlarged edition of the preceding reference.

PIERSOL, W. H.

1909. The Habits and Larval State of *Plethodon cinereus* erythronotus. Trans. Canadian Inst., Vol. VIII, pp. 469-493.

Contains a useful list of references on Amphibians.

PORTER, J. P.

- 1904. A Preliminary Study of the Psychology of the English Sparrow. Amer. Jour. Psychol., Vol. XV, pp. 313– 346.
- 1906. The Habits, Instincts and Mental Powers of Spiders, Genera Argiope and Epeira. Amer. Jour. Psychol., Vol. XVII, pp. 306–357.
- 1906. Further Study of the English Sparrow and Other Birds. Amer. Jour. Psychol., Vol. XVII, pp. 248–271.
 - Includes the Vesper Sparrow, Cowbird, Common Pigeon, Passenger Pigeon, and Red-headed Woodpecker.
- 1910. Intelligence and Imitation in Birds, a Criterion of Imitation. Amer. Jour. Psychol., Vol. XXI, pp. 1-71.
 - Studies of English Sparrow, Cowbird, Snowbird, Whitethroated Sparrow, Field Sparrow, Bluebird, Whitecrowned Sparrow, Fox, Song and Tree Sparrows, Blue Jay, Baltimore Oriole, and Crows.

POULTON, E. B.

1896. On the Courtship of Certain Acridiidæ. Trans. Ent. Soc. London, pp. 233-252.

REIGHARD, J.

1903. The Natural History of Amia calva Linnæus. Mark Anniversary Volume, pp. 57-109. REYNAUD, G.

1900. The Laws of Orientation Among Animals. Smithsonian Report for 1898, pp. 481-498.

RILEY, C. F. C.

1912. Observations on the Ecology of the Dragon-Fly Nymphs: Reactions to Light and Contact. Ann. Ent. Soc. Amer., Vol. V, pp. 273–292.

SCHEFFER, T. H.

1905. The Cocooning Habits of Spiders. Kans. Univ. Sci. Bull., Vol. III, pp. 85-114.

SEITZ, A.

1891. Allgemeine Biologie der Schmetterlinge. Zool. Jahrb., Abth. Syst. Geog. Biol. der Thiere, Bd. V, pp. 281–343.

SETON, ERNEST THOMPSON.

Life Histories of Northern Animals. Vol. I, pp. 673,
 and Vol. II, pp. 677-1267. New York.
 Valuable for life histories and habits. Extensive

bibliography.

SEVERIN, H. H. P. and H. C.

1911. An Experimental Study on the Death-Feigning of Belostoma (= Zaitha Aucct.) flumineum Say and Nepa apiculata Uhler. Behavior Monographs, Vol. I, No. 3, pp. 1-44.

SHELFORD, V. E.

1908. Life-Histories and Larval Habits of the Tiger Beetles (*Cicindelidæ*). Jour. Linn. Soc. Zoöl., Vol. XXX, pp. 157–184.

SHELFORD, V. E., and ALLEE, W. C.

1913. The Reactions of Fishes to Gradients of Dissolved Atmospheric Gases. Jour. Exp. Zool., Vol. XIV, pp. 207–266.

The reaction of fish to oxygen and carbonic acid; the latter is considered the best single index to the environment. SIMPSON, C. T.

7 The Pearly Fresh-water Mussels of the United States; their Habits, Enemies, and Diseases; with Suggestions for their Protection. U. S. Fish Comm. Bull. for 1898, Vol. XVIII, pp. 279–288.

SLADEN, F. W. L.

1912. The Humble-Bee, its Life-History and how to Domesticate it. pp. 283. London.

A very valuable account of the British species, with numerous suggestions on methods of studying them.

SMALLWOOD, M. E.

1903. The Beach Flea: Talorchestia longicornis. Cold Spring Harbor Monogr. I. pp. 27.

1905. The Salt-Marsh Amphipod: Orchestia palustris. Cold
 Spring Harbor Monogr. III. pp. 21.
 Both of these papers discuss habits and life histories.

SMITH, B. G.

1907. The Life History and Habits of Cryptobranchus Allegheniensis. Biol. Bull., Vol. XIII, pp. 5–39.
Contains references to other salamanders.

STOCKARD, C. R.

1908. Habits, Reactions, and Mating Instincts of the "Walking Stick," Aplopus Mayeri. Carnegie Inst. Pub. No. 103, pp. 43-59.

Tower, W. L.

1906. Habits and Instincts in Leptinotarsa. pp. 229–257.

In An Investigation of Evolution in Chrysomelid
Beetles of the Genus Leptinotarsa, Carnegie Inst.
Pub. No. 8. Washington, D.C.

TUTT, J. W.

1897. The Drinking Habits of Butterflies and Moths. Proc. South London Ent. and Nat. Hist. Soc., 1897, pp. [1-9].

VOIGT, W.

1904. Über die Wanderungen der Strudelwürmer in unseren

Gebirgsbächen. Verhand. naturhis. Ver. der preuss. Rheinlande, Westfalens und des Regiersungsbezirks Osnabrück, Jahrg. 61, pp. 103–178.

Shows the relation of behavior to the local distributions of Planarians.

WAGNER, W.

1907. Psycho-biologische Untersuchungen an Hummeln mit Bezugnahme auf die Frage der Geselligkeit im Tierreich. Zoologica (Chun), Bd. XIX, Heft 46, pp. 1–239.

An important study of the behavior of Bombus.

WALTER, H. E.

1906. The Behavior of the Pond Snail, Lymnæus Eleodes Say. Cold Spring Harbor Monogr. VI. pp. 35.

WASMANN, E. (Trans.)

1903. Instinct and Intelligence in the Animal Kingdom. A
Critical Contribution to Modern Animal Psychology.

pp. 171. St. Louis, Mo. From the second and
enlarged German edition.

1905. Comparative Studies in the Psychology of Ants and of Higher Animals. pp. 200. St. Louis, Mo. Translated from the revised and enlarged second German edition.

WATSON, J. B.

1908. The Behavior of Noddy and Sooty Terns. Pub. 103, Carnegie Inst. pp. 187–255.

An excellent account of bird behavior in colonial species.

WHEELER, W. M.

1903. Ethological Observations on an American Ant (Leptothorax Emersoni Wheeler). Jour. für Psychol. und Neurol., Bd. II, pp. (1–31).

1910. Ants, their Structure, Development and Behavior. pp. 663. New York.

The most useful single work on ants, ant behavior, slaves, commensals, etc.; a very important work. Extensive references.

WHITMAN, C. O.

1899. Animal Behavior. Biol. Lectures, Marine Biol. Lab., Wood's Holl, 1898, pp. 285-338.

Behavior of leech, Necturus, birds, etc.

WICKHAM, H. F.

1899. The Habits of American Cicindelidæ. Proc. Davenport Acad. Sci., Vol. VII, pp. 206-228.

YERKES, R. M.

1904. Space Perception of Tortoises. Jour. Comp. Neurol. and Psychol., Vol. XIV, pp. 17-26.

YOAKUM, C. S.

1909. Some Experiments upon the Behavior of Squirrels. Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 541-568.

IX. THE CONTINUOUS PROCESS OF ADJUST-MENT BETWEEN THE ENVIRONMENT AND THE ANIMAL, WITH SPECIAL REFERENCE TO OTHER ORGANISMS

THE DYNAMIC OR PROCESS RELATION OF ANIMAL ASSOCIA-TIONS AND AGGREGATIONS

- 1. The Struggle for Existence.
- 2. The Dynamic Relations of Aggregations and Associations, with Special Reference to Animal Associations.
 - a. The Relation of Animals to Pollination and to Plant Galls.
 - b. Subterranean and Cave Associations.
 - c. Selected References on Aggregations and Associations.

"Nothing is easier than to admit in words the truth of the universal struggle for life, or more difficult—at least I have found it so—than constantly to bear this conclusion in mind. Yet unless it be thoroughly engrained in the mind, the whole economy of nature, with every fact on distribution, rarity, abundance, extinction, and variation, will be dimly seen or quite misunderstood."—Darwin.

"Every reflective biologist must know that no living being is self-sufficient, or would be what it is, or be at all, if it were not part of the natural world, although no truth is easier to lose sight of. Living things are real things, . . . but their reality is in their interrelations with the rest of nature, and not in themselves."—W. K. Brooks. (1906.)

1. The Struggle for Existence

DARWIN, CHAS.

1876. Struggle for Existence. pp. 43-61. In On the Origin of Species, 6th ed. New York. (See Figures 2 and 3.)

Brooks, W. K.

1893. Salpa in its Relation to the Evolution of Life. Studies
Biol. Lab., Johns Hopkins Univ., Vol. V, pp. 129–211. See particularly pp. 129–170.

A remarkable and little known paper on the struggle for existence in the sea.

FORBES, S. A.

1887. The Lake as a Microcosm. Bull. Sci. Assoc. of Peoria, Illinois, 1887, pp. 77-87. Reprinted, with revisions, as from the Bull. Peoria Sci. Association, 1887, pp. 1-15.

An excellent picture of the struggle for existence in a lake, where the life is considered as a microcosm or social community.

1880. On Some Interactions of Organisms. Bull. Ill. State Lab. Nat. Hist., Vol. I, No. 3, pp. 1–18. Second Edition. 1903.

1882. The Ornithological Balance-Wheel. Trans. Ill. State Hort. Soc. for 1881, N. S., Vol. XV, pp. 120-131.

1883. The Regulative Action of Birds upon Insect Oscillations. Bull. Ill. State Lab. Nat. Hist., Vol. I, No. 6, pp. 3-32.

These three papers are very important for their discussion of the dynamic character of the struggle among organisms, and how the balance of nature is maintained.

1888. On the Food Relations of Fresh-Water Fishes: a Summary and Discussion. Bull. Ill. State Lab. Nat. Hist., Vol. II, pp. 475-538.

> A summary of the food of fishes, based upon a detailed study of the contents of their stomachs.

RODWAY, J.

1911. In the Guiana Forest, Studies of Nature in Relation to the Struggle for Life. Second Edition. pp. 326. London.

A graphic account of the biotic competition in the tropics.

JOHNSTONE, J.

1908. Conditions of Life in the Sea. pp. 332. Cambridge, England.

An excellent study of the recent quantitative investigations of marine life.

Adams, Chas. C.

1909. The Ecological Succession of Birds. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 121-154.

Ecological succession is discussed from the process standpoint. References to literature on birds.

FORBUSH, E. H.

1899. Nature's Foresters. Forty-sixth Ann. Rep. Sec. Mass. State Board Agr. for 1898, pp. 279-294.

1901. Birds as Protectors of Woodlands. Forty-eighth Ann. Rep. Sec. Mass. State Board Agr. for 1900, pp. 300-321.

1904. The Destruction of Birds by the Elements in 1903–1904. Fifty-first Ann. Rep. Sec. Mass. State Board Agr. for 1903, pp. 457–503.

1905. Special Report on the Decrease of Certain Birds, and its Causes, with Suggestions for Bird Protection. Fifty-Second Ann. Rep. Sec. Mass. State Board Agr. for 1904, pp. 429-543.

PALMER, T. S.

/ 1898. The Danger of Introducing Noxious Animals and Birds. Yearbook U. S. Dept. Agr. for 1898, pp. 87-110.

RYDER, J. A.

1892. A Geometrical Representation of the Relative Inten-

sity of the Conflict between Organisms. Amer. Nat., Vol. XXVI, pp. 923-929.

McAtee, W. L.

1912. The Experimental Method of Testing the Efficiency of Warning and Cryptic Coloration in Protecting Animals from their Enemies. Proc. Acad. Nat. Sci. Phila., 1912, pp. 281-364.

JUDD, S. D.

1899. The Efficiency of Some Protective Adaptations in Securing Insects from Birds. Amer. Nat., Vol. XXXIII, pp. 461-484.

1902. The Birds of a Maryland Farm. U. S. Dept. Agr., Div. Biol. Surv., Bull. No. 17. pp. 116.

> A study in applied ecology. One of the best detailed studies of the birds of a small tract of land and their ecological relations.

STAHL, E.

1888. Pflanzen und Schnecken. Biologische Studie über die Schutzmittel der Pflanzen gegen Schneckenfrass. Jena. Zeitschr. für Naturwiss. herausgegeben von der med.-naturwiss. Gesell. zu Jena, Bd. XXII, pp. 557-684.

A study of the means by which plants are protected(?) from snails and slugs. Numerous feeding experiments.

DAHL, F.

1908. Die Lycosiden oder Wolfspinnen Deutschlands und ihre Stellung im Haushalte der Natur. Nova Acta der Ksl. Leop.-Carol.-Deutschen Akad. der Naturf., Bd. LXXXVII, pp. 175-678. Halle.

Not seen by writer. Mr. J. H. Emerton writes that this paper "gives tables of comparative collecting in all kinds of country."

PIERCE, W. D., CUSHMAN, R. A., and HOOD, C. E.

7 1912. The Insect Enemies of the Cotton Boll Weevil. U. S. Dept. Agr., Bur. Ent., Bull. No. 100. pp. 99.

An excellent example of the character of the competition with which an animal meets when extending its range into new territory. See diagram, p. 44.

WHEELER, W. M.

1906. An Ethological Study of Certain Maladjustments in the Relations of Ants to Plants. Bull. Amer. Mus. Nat. Hist., Vol. XXII, pp. 403–418.

Competition between plants and ants.

MASSART, J., and VANDERVELDE, E. (Trans. W. MACDONALD.)

1907. Parasitism Organic and Social. Second Edition. Revised by J. Arthur Thompson. pp. 124. London. Contains many examples of responses to a parasitic environment.

Selected References on the Struggle for Existence (Alphabetically arranged)

BEAL, F. E. L.

1911. Food of the Woodpeckers of the United States. U. S. Dept. Agr., Bur. Biol. Surv., Bull. 37. pp. 64.

CHAPMAN, F. M.

1902. The Economic Value of Birds to the State. Seventh Rep. N. Y. Forest, Fish, and Game Comm., 1901, pp. 115-176. Reprint, pp. 66, 1903. Albany. Contains an extensive list of papers on the food of birds.

EICHELBAUM, E.

1910. Über Nahrung und Ernährungsorgane von Echinodermen. Wiss. Meeruntersuch, heraus. von der Komm. zur wiss. Unter. der deutsch. Meere in Kiel. N. F. Bd. XI, Abth. Kiel, pp. 187-275.

FORBES, S. A.

1883. The Food Relations of Predaceous Beetles. Twelfth Rep. State Ent. Ill., pp. 105–120.

1903. The Food of Birds. Bull. Ill. State Lab. Nat. Hist., Second Edition, Vol. I, pp. 86-161.

- 1903. Notes on Insectivorous Coleoptera. Bull. Ill. State Lab. Nat. Hist., Second Edition, Vol. I, pp. 167-176.
- 1883. The Food Relations of the Carabidæ and Coccinellidæ. Bull. Ill. State Lab. Nat. Hist., Vol. I, No. 6, pp. 33-64.
- FORBUSH, E. H.
 - 1907. Useful Birds and their Protection. Mass. State Board Agr. pp. 437. Boston.
- FOREL, A.
 - 1896. Ants' Nests. Smithsonian Report for 1894, pp. 479–505.
 - Ants' nests, and symbiosis between plants and ants.
- GAMBLE, F. W., and KEEBLE, F.
 - 1903. The Bionomics of *Convoluta roscoffensis* with Special Reference to its Green Cells. Quart. Jour. Micros. Sci., Vol. XLVII, pp. 363-431.
 - A study of the ecology of a Turbellarian worm, its food, habitat, and behavior.
- Неім.
 - 1898. The Biologic Relations Between Plants and Ants. Smithsonian Report for 1896, pp. 411–455.
- HOPKINS, A. D.
 - 1909. Insect Depredations in North American Forests and Practical Methods of Prevention and Control. U. S. Dept. Agr., Bur. Ent., Bull. No. 58, pp. 57-101.
 - Contains many facts of much ecological value showing the interrelations existing between forests and insects. Good examples of insects as initiators of successions and changes in insect associations.
- HUBBARD, H. G.
 - 1897. The Ambrosia Beetles of the United States. U. S. Dept. Agr., Div. Ent., Bull. No. 7, N. S., pp. 9-30. The relations of bark beetles to fungi.

HUBER, J.

1907. The Founding of Colonies by Atta Sexdens. Smithsonian Report for 1906, pp. 355-372.Ants and fungi.

JUDD, S. D.

1901. The Food of Nestling Birds. Yearbook U.S. Dept. Agr. for 1900, pp. 411-436.

KEEBLE, F.

Plant Animals, A Study of Symbiosis. pp. 163. Cambridge, England.

KIRBY, W., and SPENCE, W.

1859. An Introduction to Entomology; or, Elements of the Natural History of Insects: Comprising an Account of Noxious and Useful Insects, of their Metamorphoses, Food, Stratagems, Habitations, Societies, Motions, Noises, Hybernation, Instinct, Etc., Etc. pp. 607. Seventh edition, London.

MARSHALL, G. A. K., and others.

1902. Five Years' Observations and Experiments (1896–1901) on the Bionomics of South African Insects, chiefly directed to the Investigation of Mimicry and Warning Colours. Trans. Ent. Soc., London, 1902, pp. 287–584.

McAtee, W. L.

1908. Food Habits of the Grosbeaks. U. S. Dept. Agr., Bur. Biol. Surv., Bull. 32. pp. 92.

1913. Index to Papers Relating to the Food of Birds by Members of the Biological Survey in Publications of the United States Department of Agriculture, 1885–1911. U. S. Dept. Agr., Biol. Surv., Bull. No. 43. pp. 69.

The Bureau of Biological Survey, and its predecessor, the Division of Ornithology and Mammalogy, have published in the Annual Reports and in numerous bulletins elaborate studies of the foods and habits of birds and mammals.

RAUSCHENPLAT, E.

1901. Ueber die Nahrung von Thieren aus der Kieler Bucht. Wiss. Meeruntersuch. heraus. von der Komm. zur wiss. Unter. der deutsch. Meere in Kiel. N. F. Bd. V, Abth. Kiel, pp. 85-151.

RILEY, C. V.

1893. Parasitism in Insects. Proc. Ent. Soc. Wash., Vol. II, pp. 397–431.

STILES, C. W.

1893. Parasitism. Proc. Ent. Soc. Wash., Vol. III, pp. 1-7.

STILES, C. W., and HASSALL, A.

1902—. Index-Catalogue of Medical and Veterinary Zoölogy. U. S. Dept. Agr., Bur. Animal Industry, Bull. No. 39, Parts 1–36 (1912).

1908, 1912. Index-Catalogue of Medical and Veterinary Zoölogy. Subjects: Trematoda and trematode diseases, Bull. No. 37, pp. 401, 1908. — Subjects: Cestoda and Cestodaria, Bull. No. 85. pp. 467, 1912. Hyg. Lab., U. S. Pub. Health and Mar.-Hosp. Serv., Washington.

These extensive bibliographies are very useful.

SURFACE, H. A.

The Serpents of Pennsylvania. Penn. Dept. Agr.,
 Monthly Bull., Vol. IV, pp. 113-208.
 Observations on food of serpents.

1908. First Report on the Lizards of Pennsylvania. Penn. Dept. Agr., Zoöl. Bull., Vol. V, pp. 233-264. Food of lizards.

1908. First Report on the Economy of Pennsylvania Turtles. Penn. Dept. Agr., Zoöl. Bull., Vol. VI, pp. 107–195. Many observations on food.

WARD, H. B.

1910. Internal Parasites of the Sebago Salmon. U. S. Bur.
Fisheries, Bull., Vol. XXVIII, pp. 1151-1194.
"The parasitic fauna of any animal is primarily a

function of its habitat." p. 1191.

1912. The Influence of Hibernation and Migration on Animal Parasites. Proc. Seventh Inter. Zoöl. Cong., Boston, 1907, pp. 673-684.

WASMANN, E.

1894. Kritisches Verzeichniss der Myrmekophilen und Termitophilen Arthropoden. pp. 231. Berlin.

A list of Arthropods found living with ants and termites.

WEBSTER, F. M.

1903. Notes upon the Food of Predaceous Beetles. Bull. Ill. State Lab. Nat. Hist., Second Edition, Vol. I, pp. 162–166.

WEED, C. M., and DEARBORN, N.

1903. Birds in their Relations to Man. pp. 380. Phila. Extensive bibliography on the food of birds.

WHEELER, W. M.

1911. Insect Parasitism and its Peculiarities. Pop. Sci. Mo., Vol. LXXIX, pp. 431-449.

 The Effects of Parasitic and Other Kinds of Castration in Insects. Jour. Exp. Zoöl., Vol. VIII, pp. 377– 438.

ZACHARIAS, O., and others.

1891. Die Tier- und Pflanzenwelt des Süsswassers. Bd. I, pp. 380; Bd. II, pp. 369. Leipzig.

Contains several valuable and suggestive papers on the general biological relations of fresh-water plants and animals.

2. The Dynamic Relations of Aggregations and Associations, with Special Reference to Animal Associations

"A group or association of animals or plants is like a single organism in the fact that it brings to bear upon the outer world only the surplus of forces remaining after all conflicts interior to itself have been adjusted. Whatever expenditure of energy is necessary to maintain the existing internal balance amounts

to so much power locked up, and rendered unavailable for external use. In many groups this latent energy is so considerable and is liable to such fluctuations, that a knowledge of its amounts and kinds, and of the laws governing its distribution, is extremely important to one interested in measuring or foreseeing the sum and character of the outward-tending activities of the class."

-S. A. Forbes (1883).

Möbius, K.

The Oyster and Oyster-Culture. U. S. Comm. of 1883. Fish and Fisheries, Report of Comm. for 1880, Part VIII, pp. 683-751.

> On pp. 721-729 the oyster is discussed as a member of a social community or "biocönosis." He describes the succession of animals due to the overfishing of the ovster beds and the invasion of cockles and edible mussels which close up the available space and prevent the return of the ovster. One of the earliest papers to recognize clearly a social community in animals. A very important paper, which also shows the method of applying the science of ecology.

FORBES, S. A.

The Lake as a Microcosm. Reprint from Bull. Sci. Associa. of Peoria, Illinois, 1887, pp. 1-15.

> Perhaps the first paper by an American naturalist recognizing the interrelations of the social community.

WHEELER, W. M.

The Ant-Colony as an Organism. Jour. Morphology, Vol. XXII, pp. 307-325.

> The ant colony is considered as a unit. This paper furnishes an excellent example showing how "individual ecology" may become transformed into an "associational" unit.

Möbius, K.

1893. Ueber die Thiere der Schleswig-Holsteinischen Aus-

terbänke, ihre physikalischen und biologischen Lebensvershältnisse. Sitzungsber. d. Kgl. preuss. Akad. d. Wiss. zu Berlin, Jhrg. 1893, I, pp. 67–92.

The physical and biological relations of the Schleswig-Holstein oyster bank as a social community are carefully described. The animals associated are listed (in all about 100 kinds, p. 80) and their relation to the oyster is shown.

FORBES, S. A.

1909. The General Entomological Ecology of the Indian Corn Plant. Amer. Nat., Vol. XLIII, pp. 286-301.

ESPINAS, ALFRED.

1878. Des Sociétés Animales. Second Edition. pp. 588.
Paris.

Discusses associations of different species — parasites, commensals, mutuals, domestic animals; associations of the same species and related through nutrition — the colonial forms, as corals; associations based upon reproduction — the family; and associations based upon relation — as in a horde. Contains an extensive historical introduction. Valuable, although somewhat old.

PETRUCCI, R.

1906. Origine Polyphylétique, Homotypie, et Non Comparabilité directe des Sociétés Animales. L'Inst. de Sociologie (Solvay). Notes et Mémoires, Fascicule 7. pp. 126. Bruxelles.

The multiple or independent origin of "social" life in diverse lines of descent is emphasized and viewed from the comparative and phylogenetic standpoint.

WAXWEILER, E.

1906. Esquisse d'une Sociologie. L'Inst. de Sociologie (Solvay). Notes et Mémoires, Fascicule 2. pp. 306. Bruxelles.

A very important survey of sociology as a branch of

ethology or ecology. The history of ecology, and animal societies are parts which deserve special mention. A diagram, on p. 63, gives the subdivisions of ethology.

KROPOTKIN, P.

Mutual Aid a Factor of Evolution. pp. 348. New 1903. York.

PARMELEE, M.

The Science of Human Behavior. Biological and 1913. Psychological Foundations. pp. 443. New York. The Macmillan Company.

An important discussion of certain phases of animal and human responses. Communities are considered mainly from the standpoint of "aggregate ecology" and phylogeny. Little recognition is made of the "ecological association" as a fundamental unit in the study of human relations.

ADAMS, CHAS. C.

The Ecological Succession of Birds. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 121-154.

A study of changes in bird associations.

SHELFORD, V. E.

1911. Ecological Succession.

I. Stream Fishes and the Method of Physiographic Analysis. Biol. Bull., Vol. XXI, pp. 9-34

II. Pond Fishes. Biol. Bull., Vol. XXI, pp. 127-151. 1911a.

III. A Reconnaissance of its Causes in Ponds with 1911b. Particular Reference to Fish. Biol. Bull., Vol. XXII, pp. 1-38.

IV. Vegetation and the Control of Land Animal 1912. Communities. Biol. Bull., Vol. XXIII, pp. 59-99.

V. Aspects of Physiological Classification. 1912a. Biol. Bull., Vol. XXIII, pp. 331-370.

A series of detailed studies on successions in standing

and running water, and upon land. Intimately related to the following.

1913. Animal Communities in Temperate America as Illustrated in the Chicago Region; A Study in Animal Ecology. Bull. Geogr. Soc. of Chicago, No. 5. pp. (In press.) This is the most comprehensive and detailed local study of animal ecology thus far published from a distinctly modern standpoint.

CRAIG, W.

1908. The Voices of Pigeons Regarded as a Means of Social Control. Amer. Jour. Sociol., Vol. XIV, pp. 86-100.

HERRICK, C. L.

1904. The Beginnings of Social Reaction in Man and Lower Animals. Jour. Comp. Neurol. and Psychol., Vol. XIV, pp. 118-123.

HERRICK, F. H.

1912. Organization of the Gull Community. Proc. Seventh Inter. Zoöl. Cong., Boston, 1907, pp. 156-158.

WESENBERG-LUND, C.

1908. Die littoralen Tiergesellschaften unserer grosseren Seen. a. Die Tiergesellschaften des Brandungsufers. Inter. Revue der gesamten Hydrobiol. u. Hydrog., Bd. I, pp. 574-609.

Animal associations of a lake shore.

JÄGER, G.

1874. Deutschlands Thierwelt nach ihren Standorten eingetheilt. Bd. I, pp. 400; Bd. II, pp. 367 + XXIV. Stuttgart.

A popular account of the fauna of Germany arranged according to habitat. A suggestive book to the student of local associations. Worthy of imitation.

MELANDER, A. L., and BRUES, C. T.

1903. Guests and Parasites of the Burrowing Bee Halictus. Biol. Bull., Vol. V, pp. 1–27.

Gives a diagram of the Halictus biocönose on p. 27.

HUBBARD, H. G.

1894. The Insect Guests of the Florida Land Tortoise. U. S. Dept. Agr., Div. Ent., Insect Life, Vol. VI, pp. 302-315.

HUBBARD, H. G. (Appendix by Schwarz, E. A.)

1899. Insect Fauna of the Giant Cactus of Arizona: Letters from the Southwest. Psyche, Vol. VIII, Suppl., pp. 1-8, Appendix, pp. 8-14.

HUNTER, W. D., PRATT, F. C., and MITCHELL, J. D.

1912. The Principal Cactus Insects of the United States. U. S. Dept. Agr., Bur. Ent., Bull. No. 113. pp. 71.

In addition to the insects feeding upon cacti, their enemies or parasites are listed and also the scavengers, flower visitors, and incidentally associated species. This is a social community composed of 324 species of insects, and it forms an excellent foundation for a study of their interrelations. This is more ecological than is usually the case in economic reports.

MÖLLER, L.

1867. Die Abhängigkeit der Insecten von ihrer Umgebung. pp. 107. Leipzig. W. Englemann.

A very interesting and suggestive work. An excellent local habitat study from the standpoint of insects. Apparently not known to Dahl ('98, '03) in his brief outline of the history of ecology. Möller discusses the influence of climate, soil, plants, animal substances and man upon insects, and the influence of insects in the economy of nature.

LORENZ, J. R.

1863. Physicalische Verhältnisse und Vertheilung der Organismen im Quarnerischen Golfe. pp. 379. Wien.

An early and important study of the habitat and the plants and animals associated in the marine habitats. Apparently but little known. Also not mentioned by Dahl ('98, '03).

VERRILL, A. E.

1873. Report upon the Invertebrate Animals of Vineyard Sound and the Adjacent Waters, with an Account of the Physical Characters of the Region. U. S. Comm. Fish and Fisheries. Rep. on the Condition of the Sea Fisheries of the South Coast of New England in 1871 and 1872. Part I. Senate Misc. Doc. No. 61, 42d Cong., 2d Sess., pp. 295-778.

An early descriptive associational and habitat study of the marine animals of our coast. A kind of work, in its standpoint, far in advance of the times. It is remarkable that this well-known work has not been a model for other similar studies on our coast.

DAVENPORT, C. B.

1903. The Collembola of Cold Spring Beach, with Special Reference to the Movements of the Poduridae. Cold Spring Harbor Monogr. II. pp. 32.

An excellent study of a single group in a habitat, and its relation to behavior.

1903a. The Animal Ecology of the Cold Spring Sand Spit, with Remarks on the Theory of Adaptation. Decennial Pub. Univ. Chicago, Vol. X, pp. 157-176.

An associational study of a sea beach.

PETERSEN, C. G. JOH., and JENSEN, P. B.

1911. Valuation of the Sea. I. Animal Life of the Sea-Bottom, its Food and Quantity. Rep. of Danish Biol. Sta. to Board of Agriculture, Vol. XX, pp. 1–76. Transl. from Fiskeri-Beretning for 1910. Copenhagen.

The sea-bottom animals are studied as a community.

The most important study of the kind known to the writer. Similar work should be done in American waters.

Warming, E., Wesenberg-Lund, C., and others. 1904. Sur les 'vads' et les sables maritimes de la mer du nord. Kon. Danske Vid. Selsk. Skrift., Bd. VII, R. II, pp. 48–56.

The sandy flats of the sea coast of Jutland and Holland are treated as a biotic association, and from a modern ecological standpoint.

BAKER, F. C.

- 1910. The Ecology of the Skokie Marsh Area, with Special Reference to the Mollusca. Bull. Ill. State Lab. Nat. Hist., Vol. VIII, pp. 441–499.
 - A descriptive account of local molluscan associations near Chicago.
 - 1911. The Molluscan Fauna of Tomahawk Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts and Letters, Vol. XVII, pp. 200-246.

An associational study of molluscan succession. One of the very few of its kind.

HANCOCK, J. L.

- Nature Sketches in Temperate America. pp. 451.
 Chicago.
 - A discussion of the habitats of Orthoptera is given on pp. 317-418, and a classification of them on pp. 419-433, based upon the egg-laying sites.

DAHL, F.

- 1899. Das Leben der Vögel auf den Bismarckinseln nach eigenen Beobachtungen vergleichend dargestellt.
 Mitt. aus der Zool. Sammlung des Mus. für Naturk. in Berlin, Bd. I, Heft 3, pp. 107-222.
 - The bird habitats of the Bismarck Archipelago are discussed. This is the earliest detailed study of bird habitats known to the writer.
- 1901. Das Leben der Ameisen im Bismarck-Archipel, nach eigenen Beobachtungen vergleichend dargestellt. Mitt. aus. d. Zoöl. Mus. in Berlin, Bd. II, Heft 1, pp. 1–69.
 - An ecological study of ants, their nesting habitats, keys to their ecological relations, and quantitative data.

1902. Stufenfänge echter Spinnen am Riesengebirge. (Eine vergleichend ethologische Studie.) Sitz.-Ber. Ges. naturf. Freunde zu Berlin, 1902, pp. 185–203.

A comparative study of the habitats of spiders.

1903. Winke für ein wissenschaftliches Sammeln von Thieren. Sitzungs-Ber. der Gesell. naturfor. Freunde zu Berlin, 1903, pp. 444–475.

> Gives a classification of animal habitats, associations, and a brief history of their recognition by zoölogists. Compare the habitats with those given by Shelford, Physiological Animal Geography, 1911.

1893. Untersuchungen über die Thierwelt der Unterelbe. Sechster Ber. Komm. zur Wissenschaft. Untersuch. der deutschen Meere in Kiel, Jahrg. XVII-XXI, Heft III, pp. 151-185. Berlin.

> Lists the fauna of the brackish waters of the lower Elbe River, discusses their relation to the environment (salinity, etc.) and gives quantitative determinations of its frequency per square meter, as determined by digging at low tide.

MEYER, H. A., and MÖBIUS, K.

1865. Fauna der Kieler Bucht. Bd. I. Leipzig. Not seen by writer.

LOCARD, A.

1881. De L'Habitat des Mollusques. pp. 88-128. Études sur les Variations Malacologiques d'aprés la Faune Vivante et Fossile de la Partie Centrale du Bassin du Rhone. Tome II, Paris et Lyon.

> This is the most detailed study and classification of the habitats of mollusks of land and fresh-water which the writer has seen. It seems to be little known to students. The volume contains many ecological observations. The classification of habitats is often very artificial. See Von Marten's comment (Zoöl. Record for 1881, Vol. XVIII, p. 18, Moll.), which refers to English and German works along similar





Fig. 6.—Remnant of the (original) prairie animal habitat in central Illinois. Loxa, Illinois. These areas are becoming extinet rapidly. Photo. by T. L. Hankinson.

lines, but these have not been found by the writer.

KING, L. A. L., and RUSSELL, E. S.

1909. A Method for the Study of the Animal Ecology of the Shore. Proc. Roy. Phys. Soc. of Edinburgh, Vol. XVII, pp. 225-253.

An associational study of shore animals.

ORTMANN, A. E.

1896. Grundzüge der marinen Tiergeographie. pp. 96.
Jena.

Contains much of ecological value.

ENDERLEIN, G.

1908. Biologisch-faunistische Moor- und Dünen-Studien. Ein Beitrag zur Kenntnis-biosynöcischer Regionen in Westprussen. 30 Ber. des Westpreussischen Bot.-Zool. Vereins Danzig. pp. 54-238.

Adopts Dahl's (1903) classification of habitats.

HÖPPNER, H.

1901. Die Bienenfauna der Dünen und Weserabhänge zwischen Uesen und Baden. Beitr. nordwestdeutsch. Volks- und Landesk. her. vom Naturwissen. Ver. zu Bremen, Bd. XV, pp. 231-255.

PIERCE, W. D.

1904. Some Hypermetamorphic Beetles and Their Hymenopterous Hosts. Univ. of Nebraska Studies, Vol. IV, No. 2, pp. 153-190.

This gives a description of the bee community of *Epinomia triangulifera* Vachal, a list of insects in it and valuable data on their parasitic interrelations.

VESTAL, A. G.

1913. An Associational Study of Illinois Sand Prairies. Bull. Ill. State Lab. Nat. His., Vol. X, pp.

STENROOS, K. E.

1898. Das Thierleben im Nurmijärvi-See. Eine Faunis-

tisch-Biologische Studie. Acta Soc. Pro Fauna et Flora Fennica, Vol. XVII, pp. 1–259.

A descriptive associational study of a lake fauna, correlating the fauna and the vegetation.

FORBES, S. A., and RICHARDSON, R. E.

1909. The Fishes of Illinois. Ill. State Nat. Hist. Surv., Vol. III. pp. 357.

Contains numerous observations on the habitats and associations of fish; a subject hitherto greatly neglected.

WESENBERG-LUND, C.

1908. Plankton Investigations of the Danish Lakes. Danish Freshwater Biol. Lab., Op. 5, Part I, pp. 389. Part II, Copenhagen.

The only fresh-water plankton study known to the writer, which takes up the plankton from a distinctly modern ecological standpoint. An excellent summary of the problems of the fresh-water lake plankton. Abundant references to the literature.

ALLEE, W. C.

1912. Seasonal Succession in Old Forest Ponds. Trans.Ill. Acad. Sci., 1911, Vol. IV, pp. 126–131.

To determine the complete composition of an animal association observations must cover all seasons of the year. This paper and the following ones will indicate the general character of the seasonal changes.

WOOD, J. G. and T.

1886. The Field Naturalist's Handbook. pp. 167. Fourth Edition. London.

This is a British work. It gives by months the seasonal succession of moths, butterflies, birds, flowering of plants, notes on habitat, etc.

FRITSCH, C.

1850. Resultate dreijähriger Beobachtungen über die jährliche Vertheilung der Papilioniden. Sitzungsber.

der math.-naturw. Classe der K. Akad. der Wissensch. zu Wien, Jahresganges 1850, Bd. V, pp. 426–433.

- 1851. Ueber die j\u00e4hrliche Vertheilung der K\u00e4fer. Sitzungsber. der math.-naturw. Classe der K. Akad. der Wisssensch. zu Wien, Jahresganges 1851, Bd. VI, pp. 3-42.
- 1851. Resultate zweijähriger Beobachtungen über die jährliche Vertheilung der Käfer. Sitzungsber. der math.-naturw. Classe der K. Akad. der Wissensch. zu Wien, Jahresganges 1851, Bd. VII, pp. 689-710.
- 1852. Jährliche Vertheilung der Hemipteren. Sitzungsber. der math.-naturw. Classe der K. Akad. der Wissensch. zu Wien, Jahresganges 1852, Bd. IX, pp. 554-555.
 - A series of papers showing the seasonal succession in insects at Prague, Bohemia.

a. The Relation of Animals to Pollination and to Plant Galls

The relation of animals to the pollination of plants and to plant galls is a phase of the associational relation of organisms, but it has rarely been considered (if at all) from the standpoint of a biotic community. The following list will probably aid one but little in gaining this general conception, but once the student has it he will find the list of much assistance. Undoubtedly a relatively new and fertile field for investigation would be to study the interrelations of plants and their pollinators as an ecological community, the association being taken as a unit rather than the individual species of plants or animals.

BOUVIER, E. L.

1905. Bees and Flowers. Smithsonian Report for 1904, pp. 469-484. No. 1627.

KNUTH, P. (APPEL, O., and LOEW, E.)

1898–1899. Handbuch der Blütenbiologie. Unter Zugrundelegung von Hermann Müller's Werk: "Die Befruchtung der Blumen durch Insekten." Bd. I. Einleitung

und Litteratur. 1898. Leipzig. Bd. II. Die bisher in Europa und im Arktischen Gebiet gemachten Blütenbiologischen Beobachtungen. Theil 1 und 2. 1899. Leipzig.

APPEL, O., and LOEW, E.

1904–1905. (Continues Knuth.) Bd. III. Die bisher in Aussereuropäischen Gebieten gemachten Blütenbiologischen Beobachtungen. Thiel 1, 1904–1905, Leipzig; Thiel 2, 1905, Leipzig.

This is an encyclopedia on the relation of animals to the pollination of flowers. Plants are arranged systematically and the visitors are listed. In Bd. II, Th. 2, pp. 559-672, and Bd. III, Th. 2, pp. 259-470, are given systematic-alphabetic lists of animal visitors to flowers. Full references.

MÜLLER, H. (Trans. by D. W. THOMPSON.)

1883. The Fertilization of Flowers. pp. 669. London.

NEEDHAM, J. G.

1900. The Fruiting of the Blue Flag (Iris versicolor L.). Amer. Nat., Vol. XXXIV, pp. 361-386.

RILEY, C. V.

1892. The Yucca Moth and Yucca Pollination. Third Ann. Rep. Mo. Bot. Garden, pp. 99-158.

ROBERTSON, C.

1897. Flowers and Insects. Contributions to an Account of the Ecological Relations of the Entomophilous Flora and the Anthophilous Insect Fauna of the Neighborhood of Carlinville, Illinois. Trans. Acad. Sci. St. Louis, Vol. VII, pp. 151–179.

This is only one of a very extensive series of papers published in the Transactions of the St. Louis Academy, Vols. V, VI, VII, and in the Botanical Gazette—beginning with Vol. XIV, 1889, and extending to Vol. XXVIII, 1899.

TRELEASE, W.

1893. Further Studies of Yuccas and their Pollination.

Fourth Annual Rep. Mo. Bot. Garden, pp. 181-226.

BEUTENMÜLLER, W.

1904. The Insect-Galls of the Vicinity of N. Y. City. Am. Mus. Jour., Vol. IV, pp. 89-124.

A descriptive illustrated catalogue. Beutenmüller has published several important papers on galls in the Bull. Amer. Mus. Nat. History.

ADLER, H. (Trans. by C. R. STRATON.)

1894. Alternating Generations. A Bibliogical Study of Oak Galls and Gall Flies. pp. 198. Oxford.

COOK, M. T.

1905. The Insect Galls of Indiana. Twenty-ninth Ann. Rep. Dept. Geol. and Natural Resources of Indiana, 1904, pp. 801-867.

Descriptive illustrated catalogue.

HOUARD, C.

1908-1909. Les Zoocécidies des Plantes d'Europe et du Bassin de la Méditerranée. Tome I, pp. 569; II, pp. 573-1247. Paris.

KIRCHNER, O. VON.

1911. Blumen und Insekten, ihre Anpassungen aneinander und ihre Gegenseitige Abhängigkeit. pp. 436. Leipzig.

KÜSTER, E.

1911. Die Gallen der Pflanzen. Ein Lehrbuch für Botaniker und Entomologen. pp. 437. Leipzig.

Ross, H.

1911. Die Pflanzengallen (Cecidien) Mittel- und Nord Europas ihre Erreger und Biologie und Bestimmungstabellen. pp. 350. Jena.

b. Subterranean and Cave Associations

BANTA, A. M.

1907. The Fauna of Mayfield's Cave. Carnegie Inst. Pub. No. 67. pp. 114.

The cave environment, the vital optimum, and the food relations are discussed. A valuable paper.

BLATCHLEY, W. S.

1896. Indiana Caves and their Fauna. Twenty-first Ann. Rep. Geol. and Natural Resources of Indiana, pp. 121-212.

DENDY, A.

1896. The Cryptozoic Fauna of Australasia. Austr. Assoc. Adv. Sci., 1895, pp. [1-21].

On animals living under stones, logs, and bark of trees.

DIEM, K.

1903. Untersuchungen über die Bodenfauna in den Alpen. Jahrb. d. St. Gallischen Naturwiss. Gesellsch. f. 1901–1902, pp. 234–414.

HAMANN, O.

1896. Europäische Höhlenfauna. Eine Darstellung der in den Höhlen Europas lebenden Tierwelt mit besonderer Berücksichtigung der Höhlenfauna Krains. pp. 296. Jena.

MOTTER, M. G.

1898. A Contribution to the Study of the Fauna of the Grave.
A Study of One Hundred and Fifty Disinterments, with Some Additional Experimental Observations.

Jour. N. Y. Ent. Soc., Vol. VI, pp. 201-231.

A list of invertebrates, snails, crustacea, insects, etc., found in graves. Table compiled from Megnin shows the kinds of animals which invade bodies at the different stages of decay. This is a form of succession comparable to the changes in the animals living in a log at different stages of decay.

PACKARD, A. S.

1888. The Cave Fauna of North America, with Remarks on the Anatomy of the Brain and Origin of the Blind Species. Memoirs Nat. Acad. Sci., Vol. IV, pp. 1-156. Monographic treatment; extensive references to literature.

SCOTT, W.

1909. An Ecological Study of the Plankton of Shawnee Cave. With Notes on the Cave Environment. Biol. Bull., Vol. XVII, pp. 386-406.

c. Selected References on Aggregations and Associations

Adams, Chas. C.

The Coleoptera of Isle Royale, Lake Superior, and their Relation to the North American Centers of Dispersal. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 157-215. On pp. 159-163 the habitats and succession of beetles are briefly discussed.

Notes on Isle Royale Mammals and their Ecological 1909. Relations. Ibid., pp. 389-422. Brief mention of mammal associations and successions. pp. 390-393.

ANTIPA, G.

Die Biologie des Inundationsgebietes der unteren 1912. Donau und des Donaudeltas. Verhand. VIII. Inter. Zoöl.-Kongresses zu Graz, 1910, pp.163-208. Description of the biological conditions on the flooded lower Danube and its delta.

BAKER, H. B.

1911. Mollusca. pp. 121-176. In A Biological Survey of the Sand Dune Region on the South Shore of Saginaw Bay, Michigan. Ann. Rep. Mich. Board of Geol. and Biol. Survey for 1910. Lansing.

Rather full notes on mollusca, grouped by habitats.

CHAPMAN, F. M.

1909. The Habitat Groups of North American Birds in the American Museum of Natural History. Am. Mus. Nat. His., Guide Leaflet No. 28, pp. 48.

A descriptive illustrated account of the remarkable

habitat exhibits in the museum. The most remarkable series of its kind in existence. An excellent example of the educational value of ecological ideas.

DAHL, F.

1896. Vergleichende Untersuchungen über die Lebensweise wirbelloser Aasfresser. Sitzungsber. d. K. Akad. Wissen. Berlin, 1896. I, pp. 17–30.

> A study of carrion-feeding insects by the trapping method. The kinds of insects attracted change with the stage of decay. There is thus a succession. Compare with Moffat's studies (1898).

GATES, F. C.

1911. Summer-bird Life in the Vicinity of Havana, Illinois, in its Relation to the Prominent Plant Associations. Wilson Bulletin, Vol. XXIII, No. 74, pp. 1-27.

One of the relatively few associational studies of birds.

GIROD, P.

1891. Les Sociétés chez les Animaux. pp. 342. Paris.

GLEASON, H. A.

1909. The Ecological Relations of the Invertebrate Fauna of Isle Royale, Michigan. Ann. Rep. Mich. Geo. Surv. for 1908, pp. 57-78.

GRABAU, A. U.

1898. Zoölogy: Marine Invertebrates. pp. 67-96. Grabau, A. W., and Woodman, J. E. (editors). Guide to Localities Illustrating the Geology, Marine Zoölogy, and Botany of the Vicinity of Boston. Salem, Mass.

HART, C. A., and GLEASON, H. A.

1907. On the Biology of the Sand Areas of Illinois. Bull. Ill. State Lab. Nat. Hist., Vol. VII, pp. 137-272. Insect associations are discussed on pp. 220-227. Habitats are figured, and associated plants and animals are listed.



Photo. Fig. 7.—A deciduous forest (original) as an animal habitat. The Brownfield woods, Urbana, Illinois. by H. C. Chenoweth.



HANKINSON, T. L.

1910. Ecological Notes on the Fishes of Walnut Lake, Michigan. Trans. Amer. Fisheries Soc., 1910, pp. 195-206.

> One of the few papers dealing with the fish associations in a lake.

An Ecological Study of the Fish of a Small Stream. 1910. Trans. Ill. State Acad. Sci., Vol. III, pp. 23-31.

HERMS, W. B.

1907. An Ecological and Experimental Study of Sarcophagidæ with Relation to Lake Beach Débris. Jour. Exper. Zoöl., Vol. IV, pp. 45-83.

JORDAN, H.

1883. Die Binnenmollusken der nördlich gemässigten Länder von Europa und Asien und der Arktischen Länder. Nova Acta der Ksl. Leop.-Carol.-Deutschen Akad. der Naturf., Bd. XLV, Nr. 4, pp. 181-402. Halle.

> On pp. 201-253 there are many observations on molluskan ecology, including habitats, table of habitats of freshwater mollusks, and important observations on habitat variations or forms. Most of the paper is devoted to geographic problems.

KOFOID, C. A.

1903. The Plankton of the Illinois River, 1894-1899, with Introductory Notes upon the Hydrography of the Illinois River and its Basin. Part I, Bull. Ill. State Lab. Nat. Hist., Vol. VI, pp. 95-629.

> The results of a prolonged, detailed study of the Illinois River plankton; capable of an associational interpretation.

LINTNER, J. A.

1878. Report on the Insects and Other Animal Forms of Caledonia Creek, New York. Tenth Ann. Rep. N. Y. Fishery Comm. for 1877, pp. 12-36.

One of the relatively few studies of the animals of a

small stream; a census rather than an ecological study.

McCreary, O.

1909. The Ecological Distribution of the Birds of Isle Royale,
Lake Superior. Ann. Rep. Mich. Geol. Surv. for
1908, pp. 81-95.
Habitat preferences of birds.

MORSE, A. P.

1904. Researches on North American Acridiidæ. Carnegie
 Inst., Pub. 18. pp. 55.
 Associational groupings of the short-horned grass-

hoppers, with figures of habitats.

RUTHVEN, A. G.

1907. A Collection of Reptiles and Amphibians from Southern New Mexico and Arizona. Bull. Amer. Mus. Nat. Hist., Vol. XXIII, pp. 483-603.

Discusses the associations, habitats, and food of the desert species.

SCOTT, W.

1910. The Fauna of a Solution Pond. Proc. Ind. Acad. Science for 1910, pp. 395-442.
Includes a discussion of their interrelations.

SIMROTH, H.

1891. Die Entstehung der Landtiere. Ein Biologische Versuch. pp. 492. Leipzig.

STEUER, A.

1910. Planktonkunde. pp. 723. Leipzig.
A general treatise on plankton.

WATSON, J. R.

1911. A Contribution to the Study of the Ecological Distribution of the Animal Life of North Central New Mexico with Especial Attention to the Insects. First Ann. Rep. New Mexico Nat. Resource and Conserv. Comm., pp. 67-117.

Description, lists, and observations on the animal and plant associations of the arid region.

WHEELER, W. M.

1905. An Annotated List of the Ants of New Jersey. Bull.
Amer. Mus. Nat. Hist., Vol. XXI, pp. 371-403.

Ants grouped in the following associations: woodland, glade, field, meadow, heath, and sand.

1908. Comparative Ethology of the European and North American Ants. Jour. für Psychol. und Neurol., Bd. XIII, pp. 404-435. (Festschrift Forel.)

WICKHAM, H. F.

1903. The Beetles of an Oregon Beach. Ottawa Naturalist, Vol. XVII, pp. 49-52.

INDEX

habits, 78 Accidents, 62 Acrididæ, courtship, 117 habitats, 148 Adaptation, adjustive, 10 and evolution, 97 as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 Amphioxus, behavior, 116 sensory reactions, 116 Amphipods, distribution of fresh-water, 111 reproductive capacity of fresh-water, 111 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 90 and vegetation, 90
Acridiidæ, courtship, 117 habitats, 148 Adaptation, adjustive, 10 and evolution, 97 as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Age of lower organisms, 97 sensory reactions, 116 Amphipods, distribution of fresh-water, 111 reproductive capacity of fresh-water, 111 salt-marsh, habits and life history, 119 Amphithee longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 90
courtship, 117 habitats, 148 Adaptation, adjustive, 10 and evolution, 97 as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 Amphipods, distribution of fresh-water, 111 food of fresh-water, 111 reproductive capacity of fresh-water, 111 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 99 and vegetation, 90
habitats, 148 Adaptation, adjustive, 10 and evolution, 97 as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 distribution of fresh-water, 111 food of fresh-water, 111 reproductive capacity of fresh-water, 111 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
Adaptation, adjustive, 10 and evolution, 97 as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 food of fresh-water, 111 reproductive capacity of fresh-water, 111 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
adjustive, 10 and evolution, 97 and evolutive capacity of freshwater, 111 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 99 and vegetation, 90
and evolution, 97 as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 water, 111 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
as a process, 9 as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 salt-marsh, habits and life history, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
as a product, 9 theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 tory, 119 Amphithoe longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
theory, 136 Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 Amphithee longimana Smith, habits and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
Adirondacks, aquatic insects, 75 Adjustment of organisms, process of, 122 Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 and natural history, 113 Animal and plant associations of arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 arid region, 148, 149 Animal associations, and marine vegetation, 89 and vegetation, 90
Adjustment, process of, 5, 30, 31, 33, 122 Age of lower organisms, 97 Animal associations, and marine vegetation, 89 and vegetation, 90
33, 122 and marine vegetation, 89 and vegetation, 90
Age of lower organisms, 97 and vegetation, 90
Aggregate, 8 of a lake shore, 134
as agent or entity, 4 Animal behavior, 107, 121 ecology, 4, 23, 24, 133 as a process, 102
Aggregations, 27, 145 Aggregations, 27, 145 Bohn's studies in, 107
dynamic relations of, 130 limits of study, 103
Agricultural reports of the U. S. Animal communities, 133, 134
patent office, index, 72 Animal ecology,
Air, vegetational control of relative of Chicago region, 134
evaporating power of, 90 of Cold Spring sand spit, 136
vegetational control of relative of seashore, 63, 64
humidity, 90 of shore, 139
Alluvial flats, vegetational invasion, Animal galls, 143
89 Animal geography, physiological,
Alps, soil fauna, 144 Alternating generations of oak gall Animal intelligence,
flies, 143 development, 115
Ambrosia beetles, 127 evolution, 114
American lobster, natural history, nature, 115
113 raccoon, 111
Amia calva, natural history, 117 Animal life,
Amphibians, ecological distribution in New
associations of desert species, 148 Mexico, 148
collecting, 58 of sea-bottom, 63, 136
desert species, 148 of sea-bottom, food, 136
food of desert species, 148 of sea-bottom, quantity, 136

INDEX

Animal,	habitat associations, 149
mind, 106	habitats, 120
psychology, 106, 120	keys to ecological relations of, in
societies, 132, 133, 146	Bismarck Archipelago, 137
substances, influence upon in-	nesting habits of, in Bismarck
sects, 135	Archipelago, 137
visitors to flowers, systematic	nests, 127
alphabetic list, 142	North American, comparative
Animals,	ethology, 149
adjustment between environment	quantitative data on, 137
and, 122	psychology, 120
and plant galls, 141	slaves, 120
and pollination, 141, 142	structure, 120
collecting, directions, 57	Aplopus Mayeri, habits, reactions,
competing in new territory, 126	and mating instincts, 119
distribution, physiological, 101	Applied ecology, 125, 131
fresh-water, 78	Application of the process method,
of Lower Elbe, 138	86
of seashore, 146	Aquatic animals, photography, 63
of small stream, 147, 148	Aquatic Chrysomelidæ, 75
of soils, 86	Aquatic insects, 75
orientation, 118	immature, keys, 75
play, 112	in Adirondacks, 75
responses (locomotor) to white	Aquatic nematocerous Diptera,
light, 107	75
seasonal succession, 140	Aquatic resources, 24
subterranean, 58	Aquiculture, 21
variation, 96	Araneads,
Annelids, behavior of tubicolous,	activities, 115
112	courtship of, significance, 115
Ant, ethological observations on an	secondary sexual characters, 115
American, 120	Arbacia punctulata, 99
Ant-colony,	Argiope, habits and instincts, 117
as organism, 131	Arid region,
as unit, 131	animal and plant associations,
Anthophilous insect fauna, ecologi-	148, 149
cal relations to entomophilous	associations, 149
flora, 142	habitats, 149
Ants, 111	Arizona,
and fungi, 128	Amphibians, 148
and plants, 126, 127	cactus and insect fauna, 135
Arthropods living with, 130	reptiles, 148
associations, 149	Army cooks' manual, 58
associations by habitats, 149	Art,
behavior, 120	of ecology, 33
bibliography, 120	of presentation, 67
development, 120	Arthropods,
ecological study, 137	effect of caves on, 101
European, comparative ethology,	living with ants, 130
149	living with termites, 130

Artificial and "pathological" con-	Authors.
ditions, 27	guide, 68
Association, 4, 5, 6, 8, 27, 60, 132,	suggestions to, 68
139, 145	Australasia, cryptozoic fauna, 144
Associational ecology, 5, 24, 29	
Associational optimum, 94	Balance of nature, 28, 29, 123
Associational relation, of pollina-	Bark beetles, 76
tion, 141, 142	and fungi, 127
Associational study,	Bark of trees, fauna under, 144
of birds, Illinois, 146	Baseleveling, 86
of lake fauna, 140	faunal significance, 86
	Bass, black, as a microcosmic
of sand prairies of Illinois, 139	
of sea beach, 136	center, 49
of shore animals, 139	Bats, habits and sensory adapta-
Associational unit, and individual	tions of cave-inhabiting, 112
ecology, 131	Beach,
Associations,	associational study of a sea, 136
amphibian, 148	beetles of an Oregon, 149
animal, 137, 138	Beach flea,
animal, local, 134	habits, 119
ants, 149	life history, 119
as agent, 5	Beach, sea, as animal habitat,
biotic, 29	136
biotic, of sand areas, 146	Bee,
cave, 143	burrowing, 134.
climax biotic, 30	community of Epinomia triangu-
dynamic relations of, 130	lifera Vachal, 139
fish, of Illinois, 140	community, parasitic interre-
fish, in lake, 147	lations, 139
human, 10, 11	fauna of dunes, 139
lake fish, 147	humble, 119
making to order, 33	Bees,
mammal, 145	and flowers, 141
marine animals, 135, 136	as reflex machines, 109
methods of studying local, 14	Beetles,
mollusks, 137, 138	Ambrosia, 127
natural or normal, 34	bark, 76
reptiles, 148	evolution in Chrysomelid, 119
resemble plays, 47	food of predaceous, 126, 130
sand flats, 136, 137	habitats, 145
short-horned grasshoppers, 148	hymenopterous hosts, 139
succession, 91	hypermetamorphic, 139
Asterias Forbesi, direction of loco-	immature stages, 75
motion, 110	longicorn, food habits, 77
Asterias Forreri De Loriol, behavior,	of an Oregon beach, 149
105	predaceous, food, 126, 130
Atmospheric conditions about	seasonal succession of, 140
woodlands, 91	snout, 76
Atta sexdens, colonies founded by,	succession of, 145
128	Behavior, 92, 93
120	Donation, July Ju

Behavior,	caterpillars, 74
Amphioxus, 116	ecological succession of birds, 124
and natural environment, 110	economic entomology (American),
animal, 167	71, 75
animal. See also Animal behavior	environmental influences upon
animal, as a process, 102	insects, 96, 97
ants, 120	flowers and insects, 141, 142
birds, 121	food of birds, 130
Bombus, 120	forest insects, 74
Collembola, 136	fresh-water biology, 78
cuckoo, 113	Hymenoptera of N. America, 73
fixed and changeable responses,	insects, 74, 75
104	mammals, North American, 107
human, 133	medical zoölogy, 129
Hydroides Dianthus V., modi-	plant ecology, 89
fiability, 106	snout beetles, 76
ideals and conclusions, 114	veterinary zoölogy, 129
Isopods, surface and subterra-	Biocenose, 18
nean, 108	or community, 7
laws, 103	Biocenosis, 6, 7, 29
leech, 121	Bioconose, 18
Leptinotarsa, 119	Halictus, 134
Limulus, 105	Biocönosis, 131
lizard, 116	Bioconotic, 18
lobster, immature stages, 105	Biologia Centrali-Americana, 23
lower organisms, 96, 105, 107	Biologic relations of plants and ants,
method of regulation, 105	126, 127
modifiability, 93, 105, 106	Biological significance,
mud snail, 111	of dissolved gases of water, 87
nature, study of in, 39	of thermocline, 87
Necturus, 121	Biological survey,
orderly sequence, 113	of U. S., index to papers on,
organisms, 115	128
physiology, 107	ecological in methods, 114
Planarians, fresh-water, 116, 120	Biology, 1, 2, 18, 60
pond snail, 120	butterflies, 118
social wasps, 111	lower Danube delta, 145
sponges, 116	Orthoptera, 101
squirrels, 121	Physa, 110
terns, noddy and sooty, 120	relation to geological investiga-
tree frogs, 112	tion, 22
tubicolous annelids, 112	relation to man, 11, 12
Turbellarian, marine, 127	sand areas of Illinois, 146
"walking stick," 119	Biometric ideas, 63
Belostoma (= Zaitha) flumineum Say,	Biometric methods, 63
death-feigning, 118	Bionomic base line, 30
Bibliography, 71	Bionomics, 19, 21
animals and pollination, 141, 142	green cells of Convoluta roscof-
ants, 120	fensis, 127
bark beetles, 76	insects, 128
Dail Decues, 10	11150003, 120

Bionomy, marine, and stratigraphy,	statistical s
22	stomach con
Biota, postglacial dispersal, 91	study 39, 6
Biotic associations, 29, 91	Birds' eggs, co
sand areas, 146	Birds' nests, c
sandy flats of seacoast, 136, 137	Bismarck Arc
Biotic base, 30	tats, 137
Biotic community, 141	Black bass as
Biotic competition in tropics, 124	49
Biotic succession in media, 88	Blind species
Bird census, sectional, 59	
Bird habitats of Bismarck Archi-	Blissus leucopt
pelago, 137	Blond ring-do
Birds,	Blue flag, fruit
adaptations by insects to, 125	Bluebird, 117
and man, 130	Bluejay, 117
associational studies, 146	Bohn's studies
behavior, 121	107
breeding habits of North Ameri-	Boll worm, rej
can, 109	Bombus,
collecting, 58	behavior, 12
colonies, 120	see also Hun
decrease, 124	Borers, wood,
destruction by elements, 124	Brackish wat
ecological succession, 21, 124, 133	fauna, 13
economic value, 123, 126	Breeding habi
eggs of North American, 109	bark beetles
food, 126, 128, 130	birds, of No
food of nestling, 128	crawfish, 10
habitat groups, 145, 146	horned dace
habitat preferences, 148	snout beetle
habitats in summer, 146	Bufo lentigine
instinct, 113	Conte, 10
intelligence, 113	Bumble-bee,
life histories of North American,	see Bombus
109	see also Hun
	Burrowing bee
methods of study, 39, 60, 61	Butterflies,
migration, 109	
migration as a response, 109	biology, 118
noxious, introduction, 124	drinking hal
of a Maryland farm, 125	food plants,
of Isle Royale, ecological distri-	C 1 - 1 :-
bution of, 148	Cactus, Arizor
photographing, 59, 61	Cactus,
protecting woodlands, 124	giant, and it
protection, 124	insects, 135
protection of useful, 127	Caithness, veg
quantitative study, 59, 60	Caledonia Cre
regulative action upon insect	animal for
oscillations, 123	Cambarus, 113

study, 59, 60 ntents, estimating, 62 60, 61 ollecting, 58 collecting, 58 chipelago, bird habia microcosmic center, of cave fauna, origin, terus Say, 20 ve, 110 iting, 142 s in animal behavior, port on, 77 20 mble-bee ters of Lower Elbe, its, s, 76 orth America, 109 18 e, 63 es, 76 osus americanus Le 00 mble-bee e, 134 bits, 119 77 na, insect fauna, 135 ts insect fauna, 135

Cactus, Arizona, insect fauna, 135
Cactus,
giant, and its insect fauna, 135
insects, 135
Caithness, vegetation, 88
Caledonia Creek, N. Y., insects and
animal forms, 147, 148

156

Cambarus affinis, habit formation,	Changes, in land habitats, sequence,
Camp cooking, 62	Chemical stimulations, responses
Camping, 57, 60, 61, 65	to, 97
Capitalization, 69	Chemical studies on the cell and its
Carabidæ,	medium, 88
early stages, 73	Chicago, physiographic ecology, 88
food relations, 127	Chicago region, animal communi-
Carbohydrates, effect on resistance	ties, 134
to lack of oxygen, 99	Chinch-bug, 20
Carbonic acid, reaction of fish to,	Chorology, 2
118	Chrysomelid beetles, evolution, 119
Card-index system for records, 64	Chrysomelidæ,
Carrion-feeding insects, 146	aquatic, 75
Castration, parasitic, in insects, 130	food habits, 72
Catalogues of governmental publications, 65	Cicindela, 90 Cicindelidæ,
Caterpillars, 74	habits, 121
reactions, 106	life histories and larval habits,
Cave associations, 143	118
Cave environment, 144, 145	Ciliary action of shell-fish, 114
Cave fauna,	Circulars of U. S. Bureau of
European, 144	Entomology, Index to, 73
origin of blind species, 144	Clams,
Cave habitats, 112, 144	eaten by Fulgur, 110
Cave-inhabiting bats, habits and	eaten by Sycotypus, 110
sensory adaptations, 112	growth of the soft, 114
Cave life,	hard, 114
effect on Arthropods, 101	life history of the common, 114
effect on nutrition, 101	soft, 114
effect on sense organs, 101	Classification, 21
Cell and its medium, chemical studies, 88	animal habitats, 138
Census,	genetic, 56 habitats, 139
bird, 59	mollusks' habitats, 138
invertebrates, 62	physiological, 21, 101, 133, 134
of four square feet, 58, 62	Climate, influence upon insects, 135
Centers of dispersal for beetles of	Climatic sequences, 91
North America, 145	Climax biotic associations, 30
Cerambycidæ, food habits, 72	Coccinellidæ, food relations, 127
Cestoda and Cestodaria, index to	Cocooning habits of spiders, 118
literature of, 129	Cold-blooded vertebrates, digestion
Chætognatha,	influenced by season and tem-
classification, 115	perature, 100
distribution vertically, 115	Cold Spring Beach, Collembola, 136
San Diego region, 115	Cold Spring sand spit, animal
Challenger, 23 Change, laws of, 79	ecology, 136
Changes, in fresh-water habitats,	Coleoptera, centers of dispersal, North Ameri-
sequence, 86	
ведиение, оо	can, 145

Coleoptera,	Conflict between organisms, geo-
food, 76, 77	metrical representation, 125
insectivorous, 127	Conjugation, lower organisms, 97
of Isle Royale, 145	Contact, reactions of dragon-fly
transformations described, 72	nymphs to, 118
Collecting, 49, 50, 59, 61	Control of nature, 33
directions for, 39	Convoluta roscoffensis, bionomics of
natural history specimens, 63	green cells, 127
of specimens, 49, 50	Cooking, manual, 58
Collembola, Cold Spring Beach, 136	Coöperation in study, 52
Colonial forms, 132	Coral, rose, feeding reactions, 109
Colonies founded by Atta sexdens,	Corn, 132
128	entomological ecology of Indian,
Color changes of tree frogs, 112	132
Colors of insects, warning, 128	Corn plant, entomological ecology
Commensals, 132	of Indian, 132
of ants, 120	Correct composition, 68
Community,	Cotton boll weevil, insect enemies,
biotic, 141	125
Epinomia, 139	Cotton insects, 72
gulls, 106	enemies, 72
gulls, organization, 134	Cotton worm, report on, 77
living beings, 6	Courtship, Acridiidæ, 117
social, 18, 123, 131	Cowbirds, 117
See also Associations	Crane flies, 76
Communities of land animals, 91,	larval habits, 76
124	life histories, 76
vegetational control, 90, 133	Crawfish,
Comparative method, 14, 15	breeding habits, 108
limits, 56	ecological catalogue, 113
Comparative physiology, 95	egg-laying, 108
Comparative psychology 120	habit formation, 106
French work in, 107	habitats, 116
limits, 109	Pennsylvania, 116
Competition of animals, in new	stream environment, references,
territory, 126	113
Competition,	Cricket, western, 77
ants and plants, 126	Criteria,
cotton boll weevil, 125	ecological, 16
Composition,	in genetic studies, 56
correct, 68	of the psychic, 106
handbook of, 69	Criterion of imitation, 117
scientific papers, 66	Crop rotation, 28
Condition,	Crows, 117
of stress, 30, 31	Crustacea, in grave, 144
pathological, 26	Cryptic coloration, 62
Conditions,	testing by experiment, 125
artificial and "pathological," 27	Cryptobranchus Allegheniensis,
of existence, natural, 96	habits, 119
of production in the sea, 87	life history, 119

Cryptozoic fauna of Australasia,	catalogue of North American, 71
144	North American, catalogue, 71
Cuckoo,	Directions for collection, 39, 57
behavior, 113	Directory, Naturalist's, 53
life, 113	Disadvantages of non-ecological
Cultivation of turtles, 110	surveys, 31
Cycle of matter, in the sea, 87	Diseases, mussels, 119
Cycles, vegetative, causes, 88	Distribution,
Cycles, vegetative, causes, 80	fish, 64
Dace, horned, 63	Planarians, local, 119
Danish lakes, plankton investiga-	vertically of Chætognatha, San
tions, 140	Diego region, 115
Danish waters, ecology of grass-	Domestic animals, 132
wrack in, 89	psychic development of young,
Danube and its delta, biology af-	115
fected by floods, 145	Dominance, 47
Death feigning,	Dominant animals, 47, 48
Belostoma (= Zaitha) flumineum	Donaciinæ, natural history of larvæ,
Say, 118	109
instinct, 113	Dragon flies, vs. mosquitoes, 72
Nepa apiculata Say, 118	Dragon-fly nymphs,
Ranatra, 113	ecology, 118
Death of lower organisms, 97	keys, 75
Decrease of birds, 124	reactions to contact and light,
Describing environments, 45	118
Descriptive method, 14	Drinking habits,
Desert species,	butterflies, 119
of Amphibians, 148	moths, 119
of reptiles, 148	Drosophila,
Determination.	convulsive reflexes, 109
of specimens, 49, 51	reactions, 109
of specimens at museums, 52	Dunes, bee fauna, 139
Determined specimens, series of,	Dynamic conceptions, 80
52	Dynamic principles, 86
Development, 92, 93	Dynamic relation, 85
ants, 120	Dynamic relations,
effect of environment on mol-	of aggregations, 130
lusks, 100	of associations, 130
environment, 45, 46	of environment, 82
individual, 97	Dynamic standpoint, 91, 101
oysters, 112	Dynamic status, 29, 31
optima, 94	Dynamic theory and physiological
problem, 98	problems, 97
Developmental or explanatory	Dynamical interpretation, 82
method, 14, 15	Dynamics of living matter, 96
Digestion in cold-blooded verte-	
brates, influence of season and	Earthworm,
temperature, 100	behavior modifiable, 105
Diptera,	movements, 105
aquatic nematocerous, 75	quantitative studies, 58

Echinoderms, food, 126 bibliography of American, 71, 75 Ecological catalogue of crawfish, relation to ecology, 21 113 Economic problems and ecology, 114 Ecological criteria, 16 Economic value. Ecological distribution of birds of of birds, 126 Isle Royale, 148 of Pecten irradians, 108 Ecological features of evolution, 21 Economic zoölogist, 29 Ecological ideas, educational value, Economic zoölogy, 29 Educational value of ecological Ecological organization of museums, ideas, 146 22 Effects, similar, of diverse stimuli. Ecological relations. of entomophilous flora and an-Egg-laying crawfish, 108 thophilous insect fauna of Illi-Egg-laying sites, Orthoptera, 137 nois, 142 Eggs. of invertebrate fauna of Isle collecting birds', 58 of birds of North America, 109 Royale, 146 Elbe River, fauna of lower, 138 Ecological study. of cave plankton, Shawnee Cave, Emergency surgery, 65 Emotion in pigeons, 110 of lake plankton, 140 Enchytræidæ, 58 Ecological succession, 21, 90, 101, Encroachments of civilization, 26 Enemies, protection of animals birds, 124, 133 from, 125 causes in ponds, 133 English in science, better, 67 fish in ponds and streams, 133 English sparrow, 28, 117 land animals, 133 psychology, 117 mammals of Isle Royale, 145 Entomological Commission. on an oyster reef, 112 of U.S., report on cotton and boll Ecological surveys, 23, 24, 67 worm, 77 Ecological training for surveys, 32 of U. S., report on Rocky Moun-Ecology, 1, 2, 18, 19, 20, 60 tain locust, 76 and economic problems, 114 of U. S., report on western cricket, 77 and geology, 22 art of, 33 Entomological ecology of Indianassociational, 24 corn plant, 132 fish of Walnut Lake, 147 Entomological work of Townend history, 133, 138 Glover, 73 point of view, 8 Entomological writings of A. S. Packard, 74 relation to economic entomology, Entomologists' reports, relation to geology and paleon-Illinois, index, 74 tology, 10 Missouri, 77 relation to man, 10, 11 New York, 74 relation to physiology, 8 Entomology. relation to sociology, 10 bibliography of American ecorelation to teaching, 13, 14 nomic, 71, 75 research methods, 88 catalogue of publications on, 71 Economic entomology, 29, 71, 74, 75 economic, see Economic entobibliography, 74, 75 mology

Entomophilous flora, ecological re-	open and wooded areas, 91
lations to anthophilous insect	plant societies and, 64
fauna, 142	Evolution, 9
Environment, 5	and adaptation, 97
and the animal, adjustment be-	as a process, 10
tween, 122	ecological features of, 21
describing, 45	experimental, 96
development, 45, 46	mutual aid a factor of, 133
effect on development of mol-	of life and Salpa, 123
lusks, 100	organic, and baseleveling, 86
effect on insects, 96, 97	Existence,
effect on limpet, 101	natural conditions, 96
effect on snails, 100	struggle for, 2, 122, 123
fish, 64, 118	Experiment Station Record, 76
fitness, 85	Experimental evolution, 96
great changes, 26	Experimental morphology, 95
gross evolution, 86	Experimental study, limits, 103
making to order, 33	Experimental zoölogy, 96
natural, and behavior, 110	Explanatory or developmental
natural or normal, 34	method, 14, 15
orderly sequence, 79	Exploration, scientific, 63
original conditions, 25, 26	External relations, 1
parasites, 126	Extremes, influence, 98
sequence of changes, 104 Epeira, habits, instincts, 117	Eyes, frog, 110
Ephemeride, 76	insects, 110
Epinomia triangulifera Vachal, bee	slug, 110
community, 139	snail, 110
Equilibrium, relative, 30, 31	sow bug, 110
Ethological maladjustments of	various types and image-forming
ants, 126	powers, 110
Ethological observations on an ant,	worms, 110
120	
Ethological study, comparative, of	Factor of evolution, mutual aid a,
spiders, 138	133
Ethology, 18, 19, 21, 59	Factors,
and mutation theory, 22	influence of the slowest, 98
ants, comparative, 149	limiting, 98
diagram of subdivisions, 133	Family, 132
history, 133	Fauna,
subdivisions, in diagrams, 133	and flora of the sea bottom, 64
Europe,	cave, 101, 112, 143, 144, 145
cave fauna, 144	cryptozoic of Australasia, 144
plant galls, 143	Germany, classified by habitat,
Evaporating power of air, vegeta-	134
tional control of, relative,	grave, 144
Evaporation,	Indiana caves, 144 Mayfield's Cave, 143
and plant societies, 90	of brackish waters of Lower Elbe,
and soil moisture, 62	138
and post morphate, on	100

Fauna,	productivity in standing and run-
of Kiel Bay, 138	ning water, 101
pond, 148	reaction to atmospheric gases
quantitative determination in	in water, 118
brackish waters, 137	reaction to carbonic acid, 118
salt water, 111	reaction to oxygen, 118
Fanual significance of baseleveling,	rheotropism in, 115
86	sense of hearing, 116
Feeding habits,	spawning habits of, 112
slugs, 125	stream, 133
snails, 125	submerged vegetation affecting
Venus mercenaria, 114	feeding ground, 90
Feeding reactions of rose coral,	Fitness of environment, 85
109	Floods of lower Danube affecting
Feeding reflexes of shell-fish, 114	biological conditions, 145
Fertilization of flowers, 142	Florida mangroves forming ani-
Field ants, 149	mal habitats, 89
Field naturalist, 37	Flowers,
Field notes, 42	and insects, 142, 143
numbers in, 50, 51	animal visitors, 141, 142
recording, 42	bees and, 141
Field study, 36, 37, 38	fertilization, 142
plan, 36	pollination of, in relation to ani-
Field work, primary aim, 41	mals, 141, 142
Fish,	Food,
associations of a lake, 147	beetles, 126
associations of Illinois, 140	birds, 126, 128, 130
distribution, 64	butterflies, 77
ecological succession, 133	Coleoptera, 77
environment and distribution,	Echinoderms, 126
64	fish, 123
environment, index to, 118	insects, 128
feeding grounds, affected by vege-	lizards, 129
tation, 90	nestling birds, 128
food, 76, 123 food relations of fresh-water, 123	oysters, 112
habitats of Illinois, 140	predaceous beetles, 130 serpents, 129
habits, 63, 112	snails, 125
Illinois, 140	Turbellarian, 127
lateral-line organs of, functions,	woodpeckers, 126
116	Food habits,
life histories, 112	back beetles, 76
marine vegetation, 89	Cerambycidæ, 72
metabolism, 100	Chrysomelidæ, 72
methods of study, 39	Coleoptera, 77
of a small stream, 147	grosbeaks, 128
organ of sense, 113	larval Acalyptrate Muscidæ, 78
organ of taste, 113	longicorn beetles, 77
physiological responses of, 112	Rhynchophora, 72
pond, 133	snout beetles, 76

102	
Food of animals,	Galls,
in Kiel Bay, 129	animals in relation to plant, 141
of sea-bottom, 63, 136	insect, 143
Food plants,	on European plants, 143
of Coleoptera, 77	Gases,
of forest insects, 76	dissolved in water, biological
Food relations,	significance, 87
Carabidæ, 127	reaction of fish to atmospheric,
cave animals, 144	118
Coccinellidæ, 127	General physiology, 95
Forest influences, 90	General principles, value of, 41
Forest insects,	Genetic classification, 56
classified by food plants, 76	Genetic method, 15
life histories, 74	Genetic psychology, limits, 109
literature, 74	Genetic relation of types of action,
Forest invasion on alluvial flats,	106
89	Genetic standpoint, 91, 101
Forest types, determining, 89	Genetic studies, criteria in, 56
Foresters, nature's, 124	Geographic life centers, 99
Forestry, 58	Geologic processes, 86
Forests, insect depredations in, 127	Geological investigation, relation
Form regulation, 97	to biology, 22
Formation, 60	Geology and ecology, 22
French work in comparative psy-	Glade,
chology, 107	ants, 149
Fresh-water Amphipods, 111	associations of ants, 149
Fresh-water animals and plants,	Glover, Townend, entomological
biological relations, 130	work, 73
Fresh-water biology, keys to organ-	Governmental publications, cata-
isms, 78	logues, 65
Fresh-water biology, technique,	Grackles, 109
62	Grasshoppers,
Fresh-water fish, food relations, 123	short-horned, associational group-
Fresh-water habitats, changes, 86	ings, 148
Fresh-water mollusks, habitats,	short-horned, habitats, 148
147	Grass-wrack, ecology of, in Danish
Fresh-water mussels, pearly, 119 Fresh-water Planarians, reactions,	waters, 89
116	Grave, fauna of the, 144 Green cells of Convoluta roscoffensis,
Fresh-water plants and animals,	bionomics, 127
biological relations, 130	Grosbeaks, food habits, 128
Fruiting of blue flag, 142	Gross environment, evolution, 86
Fulgur eating oysters, mussels, and	Growth, 92, 93, 97
clams, 110	affected by environment, 100
Function,	influence of stimuli upon, 95
of lateral-line organs of fish, 116	quahaug, 108
of mucus of shell-fish, 114	soft clam, 114
Fungi,	Venus mercenaria, 114
and ants, 128	Guiana forest, struggle for life in,
and bark beetles, 127	124
with Sail Scottes, 121	

Gull community, organization, 106, 134 Gypsy moth, 74 enemies of, 74 Habitats, 5, 60 affected by baseleveling, 86 amphibians, 148 animal, formed by plants, 89, 91 animals classified by, 134 ants, 137, 149 beetles, 145 bird preferences, 148 birds, 137 birds in summer, 146 cave, 112, 143, 144 classification, 59, 138, 139 Collembola, 136 crawfish, 116 dune, 139 fish of Illinois, 140 formed by river floods, 145 fresh-water, 86 grasshoppers, 148 history of their recognition, 138 inland, 91 insects, 128, 135 invertebrate, 146 lake, 87 lake beach, 147 lake fauna, 140 lake, for fish, 147 land, 86 mammals, 145 marine animals, 135, 136, 146 marsh for mollusks, 137 mollusks, 138, 145, 147 mollusks, classification, 138 mollusks of land and fresh water, classification, 138 moor, 139 Oregon sea beach, 149 Orthoptera, 137 oyster, 111, 112, 131, 132 parasitic fauna, 129 pond, 148 preferences of birds, 148 reptiles, 148 sand areas, 146 sand prairie, 139

sandy sea flats, 136, 137 sea bottom, 136 shore animals, 139 spiders, 125, 138 stream, 147, 148 three dimensions, 46 Turbellarian, 127 Habits. Amphipods, 119 Amphithoe longimana Smith, 113 cave-inhabiting bats, 112 Cicindelidæ, 121 fish, 63, 112 formation in crawfish, 106 formation in the turtle, 105 Humble-bee, 118 Leptinotarsa, 119 mammals, 118 mammals of North America, 107 mating period of spiders, 115 Plethodon, 117 salamanders, 119 solitary wasps of Texas, 113 spiders, 117, 118 squirrels, 115 tortoises, 116 Venus mercenaria, 114 Halictus. biocönose, 134 guests and parasites, 134 Hearing in fish, sense of, 116 Heath ants, 149 Hemiptera. seasonal succession, 141 Hemiptera-Heteroptera, catalogue of Nearctic, 71 Hibernation, 115 influence on animal parasites, 130 insects, 128 Holland, sandy flats of, animals, 136, 137 Homarus Americanus, behavior of immature stages, 105 Homing pigeons, methods, 113 Honey-bee, natural history, 109 Horde, 132 Human associations, 11 Human behavior, biological and psychological foundations, 133

Humble-bee,	Missouri reports on insects, 77
domestication, 119	Ontario entomological society
habits, 119	reports, 72
life history, 119	Orthoptera of North America,
Humidity of air, vegetational con-	77
trol of relative, 90	papers on biological survey of
Humus, effect on animal life of	U. S., 128
soil, 100	Riley's Missouri entomological
Huttonian theory, 80	reports, 77
Hydroides Dianthus V., behavior	Index catalogue of medical and
modifiable, 106	veterinary zoölogy, 129
Hydropsyche, photographing nets	Indian corn, see Corn
of, 64	Indiana.
Hymenoptera of N. America,	caves and their fauna, 144
bibliography, 73	insect galls, 143
catalogue of species, 73	Individual development, 97
Hypermetamorphic beetles, 139	Individual ecology, 3, 8, 23, 24
Hypotheses, multiple working, 55	and the associational unit, 131
	Influence,
Ideas.	of sessile habit, 100
biometric, 63	of slowest factors, 98
life history of scientific, 57	Inland habitats, 91
Illinois,	Insect associations, changes in,
ecological relations of entomophi-	127
lous flora and anthomophilous	Insect depredations in forests, 127
insect fauna, 142	Insect enemies of cotton boll weevil,
fish, 140	125
sand areas, biology, 146	Insect fauna of the giant cactus of
sand prairies, associational study,	Arizona, 135
139	Insect galls,
State Entomologist's reports,	Europe, 143
74	Indiana, 143
Illinois River, entomology, 74	New York, 143
plankton, 147	Insect guests of Florida land tor-
Image-forming powers of eyes of various types, 110	toise, 135 Insect Life, 111
Imitation,	index, 72
and intelligence in birds, 117	Insect oscillations regulated by
criterion, 117	birds, 123
Index,	Insectivorous Coleoptera, 127
Agricultural reports of the U.S.	Insects.
patent office, 72	affecting park trees, 74
circulars, U. S. Entomology	affecting the orange, 75
Bureau, 73	affecting woodland trees, 74
Experiment Station Record, 76	and animal forms of Caledonia
Illinois State entomologist's re-	Creek, N. Y., 147, 148
ports, 74	aquatic, 74
Insect Life, 72	aquatic in Adirondacks, 75
Lintner's New York State en-	bibliography, 74, 75
tomologist's reports, 74	bionomics of, 128

T 4:	1
Insects,	warning colors of South African,
cactus, 135	128
carrion-feeding, 146	Instinct,
collecting, 58	and intelligence, 120
environmental influences upon,	birds, 113
96, 97	blindness of, 103
eyes, 110	death-feigning, 113
flowers and, 142, 143	insects, 128
food, 128	Leptinotarsa, 119
habitats, 128, 135	raccoons, 110
hibernation, 128	spiders, 117
Illinois, 74	Instruments, 57, 59
in grave, 144	Integrative action of nervous sys-
influence in economy of nature,	tem, 98
135	Intelligence,
influenced by animal substances,	and imitation in birds, 117
135	and instinct, 120
influenced by climate, 135	animal, of the raccoon, 111
influenced by environment, 135	birds, 113
influenced by man, 135	evolution of animal, 114
influenced by plants, 135	nature and development of ani-
influenced by soil, 135	mal, 115
initiating successions, 127	raccoons, 110, 111
instinct, 128	Interactions of organisms, 49, 123
life histories, 70, 73	Internal relations, 1
life histories in Lintner's New	Interpretation, dynamical, 82
York State entomologist's re-	Interrelations, 5
ports, 74	between forests and insects.
mimicry of South African, 128	127
Missouri, 77	of the social community, 131
motions, 128	parasitic, of the bee community,
Neuropteroid, synopsis, cata-	139
logue, and bibliography, 71	Introducing noxious animals, 124
New Mexico, 148	Invertebrate animals of Vineyard
New York, 74	Sound, 136
noises, 128	Invertebrate fauna of Isle Royale,
parasitic and other kinds of	ecological relations, 146
castration in, 130	Invertebrates.
parasitism, 129, 130	census, 62
preserving, 58	life histories, 70, 136
protective adaptations against	marine, 136, 146
birds by, 125	Investigation, methods of scientific.
seasonal succession, 141	56
senses, 111	Iris versicolor L., fruiting, 142
social community, 135	Isle Royale,
social life, 111	as biotic environment, 91
societies, 128	birds, ecological succession, 124,
stratagems, 128	133
study, 59	birds' habitats, 148
systematic literature, 71	ecology of Coleoptera, 145
.,	or corresponding 110

Isle Royale,	Land forms, changing, 86
ecological relations of inverte-	Land habitats, changes, 86
brate fauna, 146	Land tortoise of Florida, insec
mammals of, ecological succes-	guests, 135
sion, 145	Larval habits of tiger beetles, 118
Isophyllia, feeding reactions, 109	Larvæ,
Isopods,	catalogue, 77
of ponds and streams, responses,	classification of Lepidopterous, 73
106	Coleopterous, table of families
physiological states and rheo-	75
taxis, 106	Donaciinæ, natural history, 109
reactions of surface and sub-	Lepidopterous, 73, 78
terranean, 108	saw-fly, 78
reactions to light, 108	Lateral-line organs of fish, func
	tions, 116
Jutland, sandy flats of, animals,	Law of response to strain, 85
136, 137	Laws of change, orderly sequence
	79
Kiel Bay,	Laws of regulation,
fauna, 138	in behavior, 105
food of animals in, 129	in insect oscillations, 123
Krakatau, new flora, 89	in metabolism, 85
T 1 C	Laws of sequence,
Lack of oxygen, resistance affected	in adjustment between anima
by carbohydrates, 99	and environment, 122
Lake as a microcosm, 123, 131	in animals, 92, 93
Lake beach, habitat, 147	in environment, 79 within the animal, 92
débris, Sarcophagidæ with rela-	Leech, behavior, 121
tion to, 147	Lepidoptera,
Lake fauna.	and temperature extremes, 99
associational study, 140	field tables, 74
correlated with vegetation, 140	larvæ, 73, 78
habitats, 140	larvæ, classification, 73
Lake, fish associations of a, 147	transformations of described, 73
Lake habitat,	Leptinotarsa,
changes in, 87	behavior, 119
fish, 147	habits, 119
Lake, respiration of an inland, 87	instincts, 119
Lake shore, animal associations, 134	Leptothorax Emersoni Wheeler
Lakes,	ethological observations, 120
gases dissolved in waters, 87	Life and chemistry, 97
plankton investigations of Danish,	Life centers, geographic, 99
140	Life histories,
Land animal communities,	aquatic Nematocerous Diptera
controlled by vegetation, 90	75
vegetation and control, 124, 133	fish, 112
Land animals,	insects, 73
ecological succession, 133	insects and allied invertebrates
origin, 148	70

Life histories,	Locust, Rocky Mountain, 77
insects, in Lintner's New York	Logs, fauna under, 144
State entomologist's reports,	Louisiana, marine food mollusks,
74	114
mammals, 118	Lower organisms,
Odonata, 76	age, 97
physiological, 17	behavior, 96, 105, 107
salamanders, 119	conjugation, 97
tiger beetles, 118	death, 97
Life history,	Lycosidæ,
common clam, 114	ecology, 125
humble-bee, 119	habitats, 125
quahaug, 108	Lymnæa Columella Say, effects of
scientific ideas, 57	environment on growth, 100
Life,	Lymnæas, ecology, 108
maintenance, 97	Lymnæidæ, ecology, 108
nature, 97	Lymnœus Eleodes Say, behavior, 120
origin, 97	
Light,	Maize, see Indian Corn
and behavior of organisms, 115	Maladjustments of plants and ants,
locomotor responses of animals	126
to white, 107	Mammal associations, 145
reactions of Amphibians, 116	Mammal successions, 145
reactions of dragon-fly nymphs	Mammals,
to, 118	bibliography of North American,
reactions of Isopods to, 108	107
reactions of Planarians to, 105	collecting, 58
white, locomotor responses of	habits, 118 habits of North American, 107
animals to, 107	Isle Royale, ecological succession,
Limiting factors, 98 Limpet, environmental studies, 101	145
Limulus, behavior of early stages,	life histories, 118
105	methods of study, 39
Lists, local, 48	Man, influence upon insects, 135
Literature, limitations and value,	Mangroves, Florida, 89
82, 83, 84	Manual of style, 68
Living matter, dynamics, 96	Manuscript arrangement, 69
Lizards,	Marine animals,
behavior, 116	and vegetation, 89
food, 129	associational study, 136
Pennsylvania, 129	associations, 135
Lobster,	collecting, 57
behavior, 105, 113	distribution, 139
natural history of the American,	food of, in Kiel Bay, 129
113	habitat study, 136
Local lists, 48	Marine food mollusks of Louisiana,
Locomotion of starfish, direction,	114
110	Marine habitats of animals, 135
Locomotor responses to white light,	Marine invertebrates, 146
107	Marine life, quantitative study, 124

Marine vegetation and anim	mal Molluscan associations, local, 137
associations, 89	Molluscan succession, associational
Marsh habitats, mollusks, 137	study, 137
Maryland farm, birds of a, 125	Mollusk fisheries of Massachu-
Massachusetts shell-fisheries, 10	8 setts, 108
Mating instincts, of walking-st	ick, Mollusks,
119	associations, 138
Mating period of spiders, hab	pits, collecting, 58
115	ecology, 147
Mayfield Cave fauna, 143	effect of environment, 100
Mayfly nymphs, keys, 75, 76	habitats, 138, 145, 147
Meadow ants, 149	habitats in fresh water, 147
Media, changes in, 88	of Louisiana, marine food, 114
Medical zoölogy, bibliography,	
Metabolism, 92, 93	137
fish, 100	Mongoose, 28
in the sea, 87	Morphology, experimental, 95
Method,	Mosquitoes, Dragonflies vs. 72
comparative, limitations, 56	Moth, Yucca, 142
genetic, 56	Moths,
historical, 56	drinking habits, 119
scientific, 55, 56, 57 Methods,	reactions, 106 Mourning-cloak butterfly, photo-
biometric, 63	tropism, 116
of homing pigeons, 113	Movements, physiology, 107
of investigation, energy, ag	
and process, 56	114
of microscopic anatomy, 62	Mud snail, behavior, 111
of study, 14, 39	Multiple working hypotheses, 55
of studying birds, fish, mamm	
39	Museum exhibit of American birds,
Microcosm, 4	ecological, 145, 146
lake as a, 123, 131	Museums,
Microscopic anatomy, methods,	62 determination of specimens at, 52
Migration,	relation to ecology, 22
influence on animal parasi	tes, use of ecological ideas, 145, 146
130	Mussels,
of birds, 109	artificial propagation of fresh-
of birds, as a response, 109, 1	
Migratory plant formations, 88	diseases, 119
Mimicry, 42	eaten by Fulgur, 110
of insects of South Africa, 128	
Missouri,	enemies, 119
insects, 77	pearly fresh-water, enemies and
insects, index of reports on, 77	
Modifiability of behavior of I	
droides Dianthus V., 106	pearly fresh-water, protection, 119
Modifications,	reproduction of fresh-water, 114,
of behavior by experience 106	
of behavior by experience, 106	Mutation theory and ethology, 22

Mutual aid, a factor of evolution, 133	State entomologist's reports,
Mya arenaria,	Nomenclature,
growth, 114	ecological, for plants, 60
life history, 114	phytogeographical, 22
Myriapods,	Non-ecological surveys, 31
collecting, 58	Normal,
systematic literature, 71	as ideal, 27
ay a contract in the contract of the	conditions, 27
Nassa obsoleta, 110	departure from, 98
Natural conditions of existence, 96	processes of nature, 26
Natural environments, 26	North Carolina, oyster industry,
Natural history, 18	112
American lobster, 113	Notebook, aluminum, 44
Amia calva L., 117	Note slips, 37, 44
Amphithoe, 113	Note taking, 42, 45, 61
honey-bee, 109	Noxious animals, introducing, 124
larvæ of Donaciinæ, 109	Numbering specimens, 50, 51
starfish, 115	Numerals, 69
surveys, 23, 30	Nurmijärvi Lake, fauna and vege-
Natural preserves, 34, 38	tation, 139
Naturalist's Directory, 53	Nurture and nature, 17
Nature,	Nutrition of Arthropods, affected
and nurture, 17	by cave life, 101
control, 33	Nymphs,
Nature's foresters, 124	dragon-fly, 76
Nearctic Hemiptera-Heteroptera,	Mayfly, 76
catalogue, 71	Zygoptera, keys, 76
Nearctic spiders, 72	
Necturus, behavior, 121	Oak gall flies, and oak galls, 143
Nematocerous Diptera,	Oceanography, 21
aquatic, 75	Odonata,
aquatic, stages, 75	life histories, 76
Nepa apiculata Uhler, death-feign-	transformations described, 72
ing, 118	Œcology, see Ecology
Nervous system,	Oligochæta, 58
integrative action, 98	Ontario, Entomological Society of,
origin of, in sponges, 116	index to thirty annual reports,
regulatory action, 98	72
Nestling birds, food, 128	Optima, 98
Nests,	development, 94
ants, 127	of Chætognatha, 115
collecting birds', 58	physiological, 27
New Mexico,	vital, 27, 94
ecological distribution of animal	Optimum, 30, 94
life in, 148	associational, 94
insects, 148	departure from, 98
reptiles, 148	vital conditions, 99
New York,	vital, in caves, 144
insect galls, 143	Orange, insects affecting the, 75

Orchestia palustris, habits and life	Overton culture 6 19 121
history, 119	Oyster culture, 0, 18, 131
Orderly sequence,	development, 112
laws, 92, 93	food, 112
of behavior, 113	Oyster grounds of South Carolina,
of disturbances by man, 27	natural, 111
of environment, 79	Oyster habitat, 111
Oregon beach, beetles of an, 149	Oyster industry of North Carolina,
Orientation among animals, 118	112
Origin of land animals, 148	Oyster reef affected by storms,
Original conditions, 26, 27	112
of environment, 25, 26	Oysters,
Oriole, Baltimore, 117	eaten by Fulgur, 110
Organ of taste, fish, 113	eaten by Sycotypus, 110
Organic parasitism, 126	
Organism,	Painted turtle, discriminative abil-
ant colony as an, 131	ity, 109
as agent, 4	Papers, composition of scientific,
Organisms,	66
behavior of lower, 96, 107	Papers, preparation for publica-
geometrical representations of	tion, 65, 68
the conflict between, 125	Papilionidæ, seasonal succession,
interactions, 49, 123	140
lower, behavior, 96, 107	Paragraphing, 69
physiology, 96	Parasites, 132
responses to light, 115 Organization of gull community,	a function of habitat, 129 American Rhynchophora, 76
106, 134	burrowing bee, 134
Organs, physiology, 96	influence of hibernation on ani-
Ornithological balance-wheel, 123	mal. 130
Orthoptera,	influence of migration on animal,
biology, 101	129
classification of, by egg-laying	Sebago salmon, 129
sites, 137	Parasitic castration in insects, 130
habitats, 137	Parasitic environment, 126
index to North American, 77	Parasitic fauna, relation to habitat,
Overfishing of oyster beds, 131	129
Oxygen,	Parasitic interrelations of bee com-
effects of lack of, on sea-urchin,	munity, 139
99	Parasitism, 129
physiological effects of lack, 99	insect, 129, 130
reaction of fish to, 118	organic, 126
resistance to lack of, increased,	social, 126
99	Park trees, insects affecting, 74
Oyster, 18, 114, 131	Parks for ecological study, 38
Oyster bank, 18	Parrots, 109
as social community, 132	Passenger pigeon, 117
Oyster bed, 6	Pathological condition, 26 Pathological conditions, artificial
overfishing, 131 succession of animals on, 131	and, 27
succession of annuals on, 131	anu, 21

	Cara .
Pecten irradians,	Phytogeographical nomenclature,
economic value, 108	22, 60
growth, 108	Pigeon,
habits, 108	common, 117
life history, 108	homing, 113
Pennsylvania,	passenger, 117
crawfish, 116	Pigeons,
lizards, 129	emotion in, 110
serpents, 129	methods of homing, 113
turtles, 129	voices as means of social control,
Phase rule, 85	106, 134
Photography, 57, 59, 61, 65	Planarians,
aquatic animals, 63, 64	behavior, 120
birds, 39	distribution locally, 120
fish, 39	reactions of fresh-water, 116
mammals, 39	reactions to light, 105
nets of Hydropsyche (aquatic),	Plane table manual, 64
64	Plankton, 60, 148
Phototaxis and random movements,	ecological study, 140
105	investigations of Danish lakes, 140
Phototropism of Mourning-cloak	of Illinois river, 147
butterfly, 116	of Shawnee Cave, ecological
Phylogeny, 21, 96	study, 145
of human behavior, 133	organisms, 50
Physa, biology, 110	Plant animals, 128
Physical change, influence upon	Plant ecology, 59
animals, 85	bibliography, 89
Physiographic ecology of Chicago,	general principles, 88, 89
88	Plant formations, stable and migra-
Physiological chemistry, 95	tory, 88
Physiological classification,	Plant galls, 143
and ecological succession, 21	animals in relation to, 141
in ecology, 101, 133, 134	biology and causes of European,
Physiological conditions, 92, 93	143
Physiological life histories of plants,	Plant societies,
17	relation to evaporation, 64, 90
Physiological problems and dy-	relation to humidity, 90
namic theory, 97	study of Chicago, 88
Physiological responses,	Plant succession, 90
distribution due to, 101, 112,	relation to distribution of tiger
136	beetles, 90
of fish, 112	Plants.
Physiological states and rheotaxis	
	and ants, 126, 127
in Isopoda, 106	and snails, 125
Physiology,	forming animal habitats, 89
comparative, 95	influence upon insects, 135
general, 95	life histories, physiological, 17
of organisms, 96	seasonal succession, 140
of organs, 96	variation, 96
of reproduction, 100	Play of animals, 112

Plethodon cinereus eruthronotus.	Production, conditions of, in the
habits, 117	sea, 87
larval state, 117	Proof, correction, 68
Poduridæ,	Proof-reading, 65, 68
behavior and habitat, 136	
	Propagation, artificially, of fresh-
movements, 136	water mussels, 114, 115
Poisons, physiological effect of	Protection,
certain, 99	of birds, 124
Pollination, animals in relation to,	of useful birds, 127
141	Protective coloration, 62
Pollination of flowers, animals in	Protoplasm, influence of stimuli
relation, 141, 142	upon, 95
Pollination of Yucca, 142	Protoplasmic respiration, 97
Pond,	Psychic,
fauna, 148	criteria, 106
fish, ecological succession, 133	development of young domestic
habitat, 148	animals, 115
Isopods, 106	Psychology,
Pond snail, behavior, 120	comparative, 120
Pond, solution, 148	comparative, French work in, 107
Ponds, seasonal succession in old	English sparrow, 117
forest, 140	limits of comparative and genetic,
Porcupine mountains, 91	109
*	
Postglacial dispersal of biota, 91	of ants, 120
Potassium cyanide, effects on sea-	Publication, preparation of papers
urchin, 99	for, 65, 68
Potato beetles, see Leptinotarsa	Punctuation, 68, 69
Predaceous beetles, food, 126, 130	01
Preservation of specimens, 49, 50	Quahaug,
Preserves, natural, 34, 38	growth, 108
Principles, value of general, 41	life history, 108
Process, animal behavior as a, 102	Quantitative determination of fauna
Process method,	of lower Elbe, 138
application, 86	Quantitative study, 61
of investigation, 56	animal life of sea-bottom, 63, 124,
Process of adjustment, 30, 31	136
in organisms, 122	of birds, 59, 60
Process of response, 4	of life of sea-bottom, 63, 124,
Process standpoint, 91, 101	136
applied to vegetation, 88	Quarnerian Gulf, animals asso-
Processes,	ciated in the, 135
geologic, 86	
of behavior, 93	Rabbits, 28
of development, 93	Raccoon, animal intelligence, 111
of growth, 93	Raccoons,
of metabolism, 93	instincts, 110
of research, 55	intelligence, 110
regulatory character of physico-	sense, 110
chemical and physiological, 85	visual discrimination, 110
standpoint, 80, 81, 82	Ranatra, death-feigning, 113
E , , ,	,,

Random movements and photo-	Rhynchophora,
taxis, 105	biologies, 76
Rations, 62	food habits, 72
Record keeping, 61	parasites, 76
Recording notes, 64	Ring-dove, blond, 110
Red-headed woodpecker, 117	River entomology, Illinois, 75
Reef, ecological succession on an	
oyster, 112	Danube delta, 145
Regeneration as functional adjust-	lower Elbe, 138
ment, 98	River habitat, flooded delta, 145
Regulation,	River plankton, Illinois, 147
in behavior, 105	Rocky Mountain locust, enemies, 77
of insect oscillations by birds,	Rodentia, 107
123	Rose coral, feeding reactions, 109
regeneration as functional, 98	Running water, effect on produc-
Regulative action of nervous sys-	tivity of fish, 101
tem, 98	017103 01 11011, 202
Regulatory character of physico-	Salamanders, habits, 119
chemical and physiological	Salmon, internal parasites of Se-
processes, 85	bago, 129
Relative equilibrium, 30, 31	Salpa and evolution of life, 123
Reproduction,	Salt-marsh Amphipod, habits and
fresh-water mussels, 114, 115	life history, 119
physiology, 100	Salt-water fauna, 111. See also Ma-
Reptiles,	rine animals
Arizona, 148	San Diego region, Chætognatha of,
associations of desert species,	115
148	Sand.
collecting, 58	ants, 149
desert species, 148	areas of Illinois, biology, 146
food of desert species, 148	prairies of Illinois, associational
New Mexico, 148	study, 139
Research methods,	Sandy flats of the sea coast as a
in plant ecology, 59, 88	biotic association, 136, 137
Research,	Sarcophagidæ, relation to lake
processes, 55	beach débris, 147
speculative method in, 55	Saw-fly, larvæ, 78
Respiration.	Scallop fishery, 108
of an inland lake, 87	Scallops, 114
protoplasmic, 97	Sceloporus spinosus floridanus, be-
Response,	havior, 116
bird migration as a, 109	Schleswig-Holstein oyster bank de-
to strain, 85	scribed, 132
Responses,	Science, better English in, 67
Isopods of ponds and streams,	Scientific exploration, 63
106	Scientific ideas, life history, 57
study, 15	Scientific investigation, methods, 56
to chemical stimulations, 97	Scientific method, 55, 56, 57
Rheotaxis in Isopoda, 106	Scientific papers, composition, 66
Rheotropism in fish, 115	Scientific technique, 55

Sea anemone, behavior modifiable,	Shawnee Cave plankton, ecological study, 145
Sea beach, associational study, 136	Shell-fish,
Sea-bottom,	ciliary action, 114
animal life, 63, 136	feeding reflexes, 114
fauna and flora, 64	food, 114
quantitative study of animals, 63	function of mucus, 114
Sea,	Shell-fish industries,
conditions of life in, 134	biology, 114
conditions of production in, 87	culture, 114
cycle of matter in, 87	utilization, 114
metabolism in, 87	Shell-fisheries of Massachusetts, 108
struggle for existence in, 123	Shore, animal ecology of the, 139
valuation of the, 136	Shore animals, associational study,
Seashore,	139
animal ecology, 63, 64	Significance of courtship of Ara-
animals, 146	neads, 115
Season, influence on digestion of cold-blooded vertebrates, 100	Skokie Marsh area, ecology of mollusca, 137
Seasonal succession,	Slaves of ants, 120
animals, 140	Slug,
beetles, 140	eyes, 110
butterflies, 140	feeding habits, 125
Hemiptera, 141	Snail,
in old forest ponds, 140	eyes, 110
plants, 140	mud, 111
Sea-urchin, 99	pond, 120
resistance to lack of oxygen, 99	Snails,
resistance to potassium cyanide,	and plants, 125
99	feeding habits, 125
Sebago salmon, internal parasites,	food, 125
129	in grave, 144
Second-hand books, dealers in, 65	influence of environment on, 100
Sense organ,	Snout-beetles, 76
Arthropods, effect of caves on,	Snowbird, 117
101	Social community, 18, 123
of fish, 113	animals, 131
Senses of insects, 111	insects, 135 interrelations, 131
Sensory adaptations of cave-inhabit- ing bats, 112	oyster bank, 132
Sensory reactions of Amphioxus,	sea-bottom, 136
116	Social control, by voices among
Sequence of changes in environ-	pigeons, 106, 134
ment, 104	Social life,
Sessile habit, influence, 100	from comparative and phylo-
Serpents,	genetic standpoint, 132
food, 129	insects, 111
Pennsylvania, 129	multiple origin, 132
Sexual characters of Araneads,	origin, 132
secondary, 115	Social parasitism, 126

Social reaction,	instincts, 117
beginnings in lower animals, 134	
beginnings in man, 134	mental powers, 117
Social wasps, 117	Nearctic, 72
behavior, 111	systematic literature, 71
Societies, insects, 128	Sponges,
Sociology,	behavior, 116
a branch of ecology or ethology,	
132	Squirrels,
relation to ecology, 10, 11, 12	behavior, 121
Soil,	habits, 115
animal life influenced by humus	
and tillage, 100	Starfish,
animals of the, 86	behavior, 105
fauna of Alps, 144	locomotion, 110
influence upon insects, 135	natural history, 115
Soils,	Status, dynamic, 29, 31
moisture, 62	Stimulations, responses to chemical,
study, 58	97
Solitary wasps,	Stimuli,
habits, 116, 117	influence upon growth, 95
habits in Texas, 113	influence upon protoplasm, 95
instincts, 116	similar effects of diverse, 98
Solution pond, fauna, 148	Stones, fauna under, 144
South Africa, insects, 128	Stratigraphy, relation of marine
South Carolina, natural oyster	, , , , , , , , , , , , , , , , , , , ,
grounds, 111	Stream,
Sow bug, eyes, 110	animals of a small, 147, 148
Space, perception by tortoises, 121	environment, references to, 113
Sparrow,	fish, ecological succession, 133
field, 117	fish of a small, 147
fox, 117	habitat, 147, 148
song, 117	Isopods, 106
tree, 117	Stress, condition, 30, 31
vesper, 117	Struggle among organisms, 123 Struggle for existence, 2, 122, 123
white-crowned, 117 white-throated, 117	in a lake, 123
Spawning habits of fish, 112	in Guiana forests, 124
Specimens,	in the sea, 123
collecting natural history, 63	references, 126
collection, 49, 50	Studies, quantitative, 61
determination, 49, 51	Style brief, Wistar Institute, 68
determined, 52	Style manual, 68
numbering, 50, 51	Subterranean. See also Cave
preservation, 49, 50	Subterranean animals, 58, 86, 143,
Spiders,	144, 145
cocooning habits, 118	Subterranean Isopods, behavior, 108
collecting, 58	Succession,
habitats, 125, 138	animals in oyster beds, 131
habits, 117	associations of inland habitats, 91

Succession,	Texas,
beetles, 145	habits of solitary wasps, 113
ecological, 101	wasps, solitary, habits, 113
ecological, birds, 21, 124, 133	Theory, use, 40
ecological, in the grave, 144	Thermocline, biological significance,
ecological, on oyster reef, 112	87
in stages of decay, 144, 146	Tiger beetles,
mammal, 145	larval habits, 118
mollusks, 137	life histories, 118
seasonal, 140	relation of distribution to plant
Successions, initiated by insects, 127	succession, 90
Suggestions to authors, 68	Tipulidæ, 76
Summer-bird life near Havana,	Toad, American, 100
Illinois, 146	Tomahawk Lake, Wis., Mollusca of,
Surgery, emergency, 65	137
Surveying, 65	Tortoise,
Surveys,	Florida land, 135
ecological, 23, 67	habits, 116
ecological training for, 32	perception of space, 121
natural history, 23, 30	Tracks and tracking, 58
non-ecological, 31	Trapping, 39, 60
Sycotypus eating oysters, mussels,	Tree frogs,
and clams, 110	behavior, 112
Symbiosis, 127, 128, 130	color changes, 112
	Trees,
Talorchestia longicornis, habits and	insects affecting, 74
life history, 119	Trematoda and trematode diseases,
Tanganyika problem, 89	index to literature, 129
Taste, fish's organ of, 112	Trial and error, 104
Taxonomy, 54	Tubicolous Annelids, behavior, 112
relation to ecology, 8	Turbellarian,
Teaching, relation to ecology, 13	behavior, 127
Technique, 15, 57	ecology, 127
of fresh-water biology, 62	food, 127
scientific, 55	habitat, 127 Turtles,
Temperature, effect of extremes, 99	cultivation, 110
in open and wooded areas, 91	discriminative ability of painted,
influence on digestion of cold-	109
blooded vertebrates, 100	food, 129
lowering of, and loss of water, 99	formation of habits, 105
physiological effects of high tem-	natural history, 110
perature, 99	Pennsylvania, 129
Termites, Arthropods living with,	Turtur risorius, 110
130	Types of eyes, image-forming
Terns, noddy and sooty, behavior,	powers of various, 110
120	Typography, 68
Terrapin, diamond-back,	-0F-0
cultivation, 110	Use of theory, 40
natural history, 110	Utah, 55
77	

Vanessa antiopa Linn., phototro-	
pism, 116	ecological relations of fish, 147
Variation,	fish ecology, 147
in animals, 96	Warning coloration, 62
in plants, 96	testing by experiment, 125
statistical, 60	Warning colors, insects of South
Vegetation,	Africa, 128
and animal associations, 90	Wasps, social, 117
and control of land animal com-	behavior, 110
munities, 133 Caithness, 88	Wasps, solitary, habits, 116, 117
changes in, 88	habits, of Texas, 113
controlling land animal communi-	instincts, 116, 117
ties. 90	Water,
correlated with lake fauna, 140	loss of and lowering of tempera-
development and structure, 88	ture, 99
invading alluvial flats, 89	running, effect on productivity of
invading new land surface, 89	fish, 101
Vegetational change, influence upon	standing, effect on productivity
animals, 85	of fish, 101
Vegetational control,	Weights and measures, 69
of relative evaporating power of	Wild life,
the air, 90	photography, 61
of relative humidity of air,	study, 61
90	Windermere, Lake, 90
Vegetative cycles, causes, 88	Wisdom, blindness of, 103
Venus mercenaria,	Wistar Institute, style brief, 68
growth, 108, 114	Wood borers, 77
habits, 114	Woodcraft, 61
life history, 108	Woodland,
Veterinary zoölogy, bibliography,	ants, 149
129	associations of ants, 149
Vineyard Sound, invertebrate ani-	atmospheric conditions about, 91
mals of, 136	birds as protectors, 124
Visual discrimination in raccoons,	Woodland trees, insects affecting, 74
110	Woodpecker, red-headed, 117 Woodpeckers, food, 126
Vital conditions, optimum, 99 Vital optimum, 94	Worms, eyes, 110
Voices of pigeons as means of social	Worlds, eyes, 110
control, 106, 134	Yucca,
Volcanic activity and new land	moth, 142
surface, 89	pollination, 142
Volcanic islands, new flora, 89	0
	Zoölogical Record, 70
"Walking stick,"	Zoölogist, economic, 29
behavior, 119	Zoölogy, experimental, 96
habits, 119	Zostera marina, ecology in Danish
mating instincts, 119	waters, 89
reactions, 119	Zygoptera, life histories, 76



INDEX TO NAMES

Adams, Chas. C., 21, 22, 86, 91, 94, 99, 124, 133, 145 Adler, H., 143 Aldrich, J. M., 71 Allbutt, T. C., 66 Allee, W. C., 106, 118, 140 Andrews, E. A., 108 Antipa, G., 145

Appel, O., 141, 142 Bachmetjew, P., 96 Baker, F. C., 108, 137 Baker, H. B., 145 Baldwin, E. L., 112 Balfour, I. B., 89 Bancroft, W. D., 85 Banks, N., 58, 65, 71 Banta, A. M., 108, 143 Baskerville, C., 97 Bates, 23, 42 Beal, F. E. L., 126 Belding, D. L., 108 Belt, 23 Bendire, C., 109 Bethune, C. J. S., 72 Betten, C., 75 Beutenmüller, W., 72, 143 Birge, E. A., 87 Blackman, 94, 98 Blackwall, J., 108 Blatchley, W. S., 144 Boas, F., 56 Bohn, G., 107 Bouvier, E. L., 141 Böving, A. G., 109 Brandt, K., 87 Bretscher, K., 58 Brooks, W. K., 3, 17, 36, 42, 79, 82, 122, 123 Brues, C. T., 134 Brunner, J., 58

Buffon, 20

Burdon-Sanderson, J. K., 1, 18 Burns, F. L., 59 Buttel-Reepen, H. von, 109

Calkins, M. W., 109 Carpenter, F. W., 109 Case, E. C., 21 Cassell, 53 Casteel, D. B., 109 Caudell, A. N., 73 Chamberlin, T. C., 55, 86 Chapman, F. M., 39, 59, 61, 126, 145 Chittenden, F. H., 72 Clarke, W. E., 109 Clements, F. E., 21, 59, 61, 88 Clessin, S., 100 Coker, R. E., 110 Cole, L. J., 110 Cole, L. W., 110 Colton, H. S., 100, 110 Comstock, J. H., 43, 59, 72 Congdon, E. D., 107 Cook, M. T., 143 Cook, O. F., 30, 90 Coquillett, D. W., 73 Coues, E., 107 Cowles, H. C., 88 Craig, W., 106, 110, 134 Cramer, F., 56 Crampton, C. B., 88 Cresson, E. T., 73 Currie, R. P., 73 Curtis, W. C., 114 Cushman, R. A., 125

Dahl, F., 18, 59, 61, 125, 135, 137, 139, 146
Darwin, Charles, 2, 20, 23, 41, 56, 122, 123
Davenport, C. B., 60, 95, 136
Davis, H. B., 111

Davis, W. M., 67, 86 Dawson, J., 110 Dean, B., 111 Dearborn, N., 130 Dendy, A., 144 De Vinne, T. L., 68 Diem, K., 144 Dimmock, G., 73 Dimon, A. C., 111 Dodge, C. R., 73 Dyar, H. G., 73

Edwards, H., 73
Eichelbaum, E., 126
Embody, G. C., 111
Emerton, J. H., 125
Emery, C., 21
Enderlein, G., 59, 139
Enteman, M. M., 111
Ernst, A., 89
Espinas, Alfred, 132

Fabre, J. H., 111 Felt, E. P., 74 Fernald, C. H., 74 Fernald, J. C., 66 Fernow, B. E., 90 Fischer, E., 98, 99 Flahault, C., 22, 60 Florentin, R., 111 Folsom, J. W., 74 Forbes, S. A., 20, 21, 23, 49, 60, 74, 123, 126, 131, 132, 140 Forbes, W. T. M., 74 Forbush, E. H., 74, 124, 127 Forel, A., 111, 127 Fritsch, C., 140 Fuller, G. D., 90 Fürth, O. von, 95

Gamble, F. W., 127 Ganong, W. F., 17 Gates, F. C., 146 Geisler, M. H., 109 Gibson, W. H., 60 Gilbert, G. K., 55 Gill, T., 112 Girod, P., 146 Gleason, H. A., 146 Glover, Townend, 73 Grabau, A. W., 22, 146 Grave, C., 112 Greeley, A. W., 99 Groom, P., 89 Groos, K., 112 Gurley, R. R., 112

Hadley, P. B., 105 Haeckel, E., 2, 19 Hahn, W., 112 Hamann, O., 144 Hammarsten, O., 95 Hancock, J. L., 137 Hankinson, T. L., 147 Hargitt, C. W., 103, 112 Harrington, M. W., 90 Harris, J. A., 113 Hart, C. A., 75, 146 Hartman, C., 113 Hassall, A., 129 Hayden, F. P., 77 Heim, 127 Henderson, L. J., 85 Hensen, V., 60 Henshaw, S., 71, 75 Herdmann, W. A., 21 Herms, W. B., 147 Herrick, C. J., 113 Herrick, C. L., 39, 61, 97, 134 Herrick, F. H., 102, 106, 113, 134 Hodge, C. F., 113 Holmes, S. J., 97, 104, 105, 107, 113 Hood, C. E., 125 Hopkins, A. D., 43, 61, 127 Höppner, H., 139 Houard, C., 143 Hubbard, H. G., 75, 127, 135 Huber, J., 128 Huggins, G. E., 106 Hunter, W. D., 135 Huxley, T. H., 11, 12, 13, 17

Jacob, 19 Jager, G., 134 Jennings, H. S., 92, 96, 97, 102, 105, 107, 114 Jensen, P. B., 63, 96, 136 Jevons, S., 56 Job, H. K., 61 Johannsen, O. A., 75 Johnstone, J., 87, 124 Jordan, H., 147 Juday, C., 87 Judd, S. D., 125, 128

Kearton, R., 39, 61 Keeble, F., 127, 128 Keller, C., 100 Kellogg, J. L., 114 Kephart, H., 61 Keyes, C. R., 56 King, L. A. L., 63, 139 Kirby, W., 19, 128 Kirchner, O. von, 143 Knab, F., 73 Knauthe, K., 62, 100 Knuth, P., 141, 142 Kofoid, C. A., 147 Kropotkin, P., 133 Küster, E., 143

Lamborn, R. H., 72 Lane, E. C., 108 Lang, A., 100 Lankester, E. R., 19 LeBon, G., 57 Lee, A. B., 62 Lefevre, G., 114 Lewes, G. H., 66 Lillie, F. R., 97 Livingston, B. E., 62 Lintner, J. A., 74, 147 Locard, A., 100, 138 Loeb, J., 96 Loew, E., 141, 142 Long, F. M., 110 Lorenz, J. R., 135 Lyon, E. P., 99, 115

McAtee, W. L., 58, 62, 125, 128 McCreary, O., 148 Macdonald, W., 126 MacDougal, R., 57 MacGillivray, A. D., 75 Mandel, J. A., 95 Marshall, F. H., 100 Marshall, G. A. K., 128 Martin, J., 77 Massart, J., 126 Mast, S. O., 107, 115

Mathews, A. P., 97 Mayer, A. G., 106 Mead, A. D., 115 Melander, A. L., 134 Meldola, R., 55 Meyer, H. A., 138 Miall, B., 111 Michael, E., 115 Middleton, N., 77 Mill, J. S., 56, 79 Miller, N., 100 Mills, W., 115 Minot, C. S., 71 Mitchell, J. D., 135 Möbius, K., 6, 18, 29, 131, 138 Moffat, 146 Möller, L., 135 Montgomery, T. H., 115 Moore, J. E. S., 89 Morgan, T. H., 96, 97 Morse, A. P., 148 Motter, M. G., 144 Müller, H., 141, 142

Needham, J. G., 75, 76, 142 Neumayer, G. von, 63 Newman, H. H., 116

Orcutt, W. D., 69 Ortmann, A. E., 116, 139 Ostenfeld, C. H., 89

Packard, A. S., 74, 76, 144 Packard, W. H., 99 Palmer, T. S., 124 Parker, G. H., 116 Parmelee, M., 133 Patterson, J. T., 116 Pearl, R., 63, 105, 116 Pearse, A. S., 107, 116 Pearson, K., 56 Peckham, E. G., 116 Peckham, G. W., 116 Peters, A. W., 88 Petersen, C. G. Joh., 61, 63, 64, 136 Petrucci, R., 132 Pierce, W. D., 76, 125, 139 Piersol, W. H., 117 Playfair, J., 80 Porter, J. P., 117

Poulton, E. B., 117 Pratt, F. C., 135 Przibram, H., 96 Pütter, A., 95

Rauschenplat, E., 129 Reighard, J., 39, 63, 117 Reynaud, G., 118 Richards, H. M., 97 Richardson, R. E., 140 Rickard, T. A., 67 Riddle, O., 100 Riley, C. F. Curtis, 118 Riley, C. V., 76, 77, 129, 142 Robertson, C., 142 Rodway, J., 124 Rosenthal, J., 95 Ross, H., 143 Russell, E. S., 63, 101, 139 Ruthven, A. G., 91, 148 Ryder, J. A., 124

St. Hilaire, I. Geoffray, 19 Salisbury, R. D., 86 Sanderson, E. D., 44, 64 Schäfer, E. A., 97 Scheffer, T. H., 118 Schiemenz, P., 101 Schröter, C., 22, 60 Schwarz, E. A., 77, 135 Scott, F. N., 66 Scott, W., 145, 148 Scudder, S. H., 77 Seitz, A., 118 Semper, K., 96 Seton, Ernest Thompson, 118 Severin, H. C., 118 Severin, H. H. P., 118 Seward, A. C., 89 Shelford, V. E., 21, 90, 94, 101, 112, 118, 133, 138 Sherrington, C. S., 98 Simpson, C. B., 64 Simpson, C. T., 119 Simroth, H., 148 Sladen, F. W. L., 119 Smallwood, M. E., 119 Smith, B. G., 119 Soule, C. G., 106 Spence, W., 19, 128

Spencer, Herbert, 92 Sprengel, 19 Stahl, E., 125 Stenroos, K. E., 139 Steuer, A., 148 Stiles, C. W., 129 Stockard, C. R., 119 Straton, C. R., 143 Strong, 20 Sumner, F. B., 64 Surface, H. A., 129

Thomas, C., 76, 77 Thompson, D. W., 142 Tower, W. L., 119 Townsend, C. H. T., 78 Transeau, E. N., 64, 90 Trelease, W., 142 Turner, 107 Tutt, J. W., 119

Uexkuell, J. von, 107

Vandervelde, E., 126 Van Hise, C. R., 40, 43, 55, 56, 86 Varigny, H. de, 96 Vaughan, T. W., 89 Vaux, C. B., 68 Vergil, 19 Vernon, H. M., 96 Verrill, A. E., 136 Verworn, M., 95 Vestal, A. G., 139 Vire, A., 101 Voigt, W., 119 Von Marten, 138 Vosseler, J., 101

Wagner, W., 120
Wainwright, D. B., 64
Wallace, 19, 23, 41
Walter, H. E., 105, 120
Walther, J., 22
Ward, H. B., 78, 129
Warman, P. C., 67
Warming, E., 89, 136
Washburn, M. F., 106, 107
Wasmann, E., 18, 120, 130
Watson, J. B., 107, 120

Watson, J. R., 148 Waxweiler, E., 132 Webster, F. M., 130 Weed, C. M., 130 Weiss, F. E., 90 Wendell, B., 66 Wesenberg-Lund, C., 134, 136, Wheeler, W. M., 18, 19, 22, 107, 111, 120, 126, 130, 131, 149 Whipple, G. C., 78 White, C. A., 22 Whitman, C. O., 103, 121 Wickham, H. F., 121, 149 Wilson, E. B., 98 Wilson, H. M., 65 Winterstein, H., 95

Wood, G. M., 68 Wood, J. G., 140 Wood, T., 140 Woodman, J. E., 146 Woodworth, J. B., 86 Woolley, E. C., 69 Wright, A. H., 64

Yearsley, M., 111 Yerkes, A. W., 106 Yerkes, R. M., 105, 106, 107, 121 Yoakum, C. S., 121

Zacharias, O., 130 Zoethout, W. D., 99 Zon, Raphael, 89



THE following pages contain advertisements of a few of the Macmillan books on kindred subjects



Genetics. An Introduction to the Study of Heredity

By HERBERT EUGENE WALTER

Assistant Professor of Biology, Brown University

Cloth, 12mo, \$1.50 net; postpaid, \$1.63

In his "Genetics" Professor Walter summarizes the more recent phases of the study of heredity and gives to the non-technical readers a clear introduction to questions that are at present agitating the biological world.

Professor Walter's conception of sexual reproduction is that it is a device for doubling the possible variations in the offspring, by the mingling of two strains of germ plasm. The weight of probability, he concludes, is decidedly against the time-honored belief in the inheritance of acquired characters. Professor Walter also predicts that the key to this whole problem will be furnished by the chemist, and that the final analysis of the matter of the "heritage carriers" will be seen to be chemical rather than morphological in nature. In the practical application of this theory to human conservation or eugenics, it would follow that the only control that a man has over the inheritance of his children is in selecting his wife. Professor Walter holds, if only modifications of the germ plasm can count in inheritance, and if these modifications come wholly from the combination of two germ plasms, then the only method of hereditary influence is in this selection.

"I find that it is a very useful study for an introduction to the subject. Professor Walter has certainly made one of the clearest statements of the matters involved that I have seen, and has made a book which students will find very useful because he keeps everything in such entirely simple and clear outlines, and at the same time he has brought the book up to date."—PROFESSOR LOOMIS of Amherst College.

"I am much pleased with it and congratulate you upon securing so excellent a treatment. It is one of the most readable scientific books I have, and goes unerringly to the fundamentals of our most recent advances in the experimental study of heredity as well as those of the older studies."—PROFESSOR GEORGE H. SHULL, Cold Spring Harbor, Long Island, N. Y.

"There was a decided need for just such a work. The book strikes me as most excellently done."—PROFESSOR H. S. JENNINGS, Johns Hopkins University.

THE MACMILLAN COMPANY

The Fitness of the Environment

BY LAWRENCE J. HENDERSON

Assistant Professor of Biological Chemistry in Harvard University

Cloth, 12mo, \$1.50 net

"Darwinian fitness is compounded of a mutual relationship between the organism and the environment. Of this, fitness of environment is quite as essential a component as the fitness which arises in the process of organic evolution; and in fundamental characteristics the actual environment is the fittest possible abode of life." Such is the thesis which this work seeks to establish through discussions of the physical and chemical characteristics of life and cosmogony, and through critical study of the properties of matter in their biological relations.

Water and carbonic acid are shown to be the primary constituents of the environment. Analysis shows their properties, together with those of the component elements, hydrogen, oxygen, and carbon, to make up a series of maxima, among all known compounds and elements, so numerous, so varied, and so highly favorable, to the organic mechanism that the fitness of the world for life assumes an importance not less than the fitness which has been won by adaptation in the course of organic evolution.

A final chapter discusses the bearing of these conclusions upon theories of organic evolution, modern vitalism, including the views of M. Bergson, and the old natural theology, and seeks to harmonize implications of design with the mechanistic view of nature.

THE MACMILLAN COMPANY

COLLEGE ZOÖLOGY

By

ROBERT W. HEGNER, Ph.D.

Assistant Professor of Zoölogy in the University of Michigan

Illustrated, Cloth, 12mo, xxiv + 733 pp., \$2.60 net

This book is intended to serve as a text for beginning students in universities and colleges, or for students who have already taken a course in general biology and wish to gain a more comprehensive view of the animal kingdom. It differs from many of the college text-books of zoölogy now on the market in several important respects: (I) the animals and their organs are not only described, but their functions are pointed out; (2) the animals described are in most cases native species; and (3) the relations of the animals to man are emphasized. Besides serving as a text-book, it is believed that this book will be of interest to the general reader, since it gives a bird's-eye view of the entire animal kingdom as we know it at the present time.

Within the past decade there has been a tendency for teachers of zoölogy to pay less attention to morphology and more to physiology. As a prominent morphologist recently said, "Morphology . . . is no longer in favor . . . and among a section of the zoölogical world has almost fallen into disgrace" (Bourne). The study of the form and structure of animals is, however, of fundamental importance, and is absolutely necessary before physiological processes can be fully understood; but a course which is built up on the "old-fashioned morphological lines" is no longer adequate

for the presentation of zoölogical principles.

The present volume has not been made by merely adding a description of the vertebrates to the author's "Introduction to Zoölogy" (for a brief account of which see the last pages of this circular). On the contrary, it is a new work throughout, although the same general method of treatment, which proved so successful in the earlier book, has been employed in this one. Similarly, in the preparation of this book the author has submitted the manuscript of each chapter to a scholar and teacher of unquestioned authority in the particular field. The criticisms and suggestions thus secured have greatly increased both the accuracy and the practicability of the text.

THE MACMILLAN COMPANY

Publishers

64-66 Fifth Avenue

New York

An Introduction to Zoölogy

By

ROBERT W. HEGNER, Ph.D.

Instructor in Zoölogy in the University of Michigan

Illustrated, 12mo, \$1.90 net

Only a few animals belonging to the more important phyla, as viewed from an evolutionary standpoint, are considered. They are, however, intensively studied in an endeavor to teach the fundamental principles of Zoölogy in a way that is not possible when a superficial examination of types from all the phyla is made. Furthermore, morphology is not specially emphasized, but is coördinated with physiology, ecology, and behavior, and serves to illustrate by a comparative study the probable course of evolution. The animals are not treated as inert objects for dissection, but as living organisms whose activities are of fundamental importance. No arguments are necessary to justify the "type course," developed with the problems of organic evolution in mind, and dealing with dynamic as well as static phenomena.

"I have read your chapter (The Crayfish and Arthropods in General) and can express my satisfaction with reference to the general arrangement of the matter, as well as with reference to the detail. The whole treatment is up to date, taking account of the modern advancement in our knowledge of the crayfishes, and, chief of all, the more important features in the natural history of these animals are very properly separated from the unimportant ones. I think this chapter gives the essence of what we know about crayfishes, and any student might use the book advantageously. In fact, I know no other text-book which gives such a wealth of information upon so few pages."— Professor A. E. Orthmann, Carnegie Museum.

"The plan is very satisfactory, and the book will be very instructive for class use. I am very glad that you have chosen the bee as your insect type." (Chapter XII.) — Dr. E. E. PHILLIPS, Department of Agriculture, Washington, D.C.

THE MACMILLAN COMPANY

Publishers

64-66 Fifth Avenue

New York

Household Bacteriology

BY

ESTELLE D. BUCHANAN, M.S.

Recently Assistant Professor of Botany, Iowa State College

AND

ROBERT EARLE BUCHANAN, Ph.D.

Professor of Bacteriology, Iowa State College, and Bacteriologist of the Iowa Agricultural Experiment Station

Cloth, 8vo, xv + 536 pp., index, \$2.25 net

The word Household is used as an extension rather than a limitation of the title. In a thoroughly scientific manner the authors treat the subject-matter of general as well as of household bacteriology and include, therefore, the true bacteria as well as the yeasts, molds, and protozoa. The volume is, therefore, a general textbook of micro-biology in which special attention is given to those problems which are of particular interest to the student of household science. The main divisions of the book treat (I) the microorganisms themselves, (2) fermentations with special reference to those affecting foods, (3) the relations of bacteria and other micro-organisms to health. A fully illustrated key (comprising 37 pages) to the families and genera of common molds, supplements the unusually extended discussion of the morphology and classification of yeasts and molds, and makes possible the satisfactory identification of all forms ordinarily encountered by the student. The work embodies the results of the most recent researches. The book is exceptionally well written, the different topics are treated consistently and with a good sense of proportion. While concise in statement, it is thorough in method and scope. It is, therefore, well adapted for use as a text not only for students of household science, but also for those to whom it is desired to present the science of bacteriology from an economic and sanitary rather than from a strictly medical point of view.

"The book is a concisely written work on micro-biology, a branch of economic science that the public is beginning gradually to understand, has important relationship to the total welfare and prosperity of the community.

The manual can be recommended as a very good elementary bacteriology. It comprises about all there is of practical domestic value."

- Boston Advertiser.

THE MACMILLAN COMPANY

Publishers

64-66 Fifth Avenue

New York

A Laboratory Guide to the Study of Parasitology

By W. B. HERMS

University of California, Berkeley, California; Author of "Malaria: Cause and Control"

Cloth, 8vo, xv + 72 pages, 80 cents net

PART I - MEDICAL ENTOMOLOGY

PART II - HELMINTHOLOGY

PART III - LIFE HISTORY STUDIES ON LIVING PARASITES

With the rapid growth of parasitology there is also a growing demand for laboratory instruction in this field. The author's greatest desire during the time that he has been engaged in teaching this subject has been to place the work upon a good systematic footing, giving it proper rank with other phases of applied biology. The exercises in this volume are based upon two standard courses given at the University of California during the last four years. These courses are Human Parasitology (first half-year) and Veterinary Parasitology (second half-year). Each exercise has had careful testing in the laboratory and is practical.

The aim of this guide is to give the student a wide, practical view of the field, so that he may have a fair grasp of the general subject in its application to the health and well-being of man and beast. The exercises are in sufficient detail to enable the student to continue work on some specific group or species if he so chooses.

THE MACMILLAN COMPANY









